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LEGG-CALVÉ-PERTHES DISEASE

A Comparative Study
by
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PREFACE

The studies to be reported in this volume were started in 1967 while I was clinical assistant at the Århus University. I am very grateful to Professor E. Thomasen of the Orthopaedic Hospital, Århus, for having given me access to the patient material from this Hospital, for his interest in my study, for help and guidance in its performance.

From the very earliest phase, I have been in touch with the person in Denmark who knows most about the disease in question, Johannes Meyer, M.D., former Head of the Seaside Hospital, Refsnæs. I owe a debt of deep gratitude to Dr. Meyer for the part he has taken in my studies, for numerous discussions, oral and in writing, through the years, and for his never failing and ever vivid interest in the job. For access to the files of case notes and X-ray films in the Refsnæs Hospital I am greatly indebted also to its present Head, Hans Bohr, M.D., who displayed a constant interest in the progress and results of the study and contributed by instructive discussions. Thanks are due, moreover, to the staff of the Refsnæs Hospital for extensive obligingness and help as well as for hospitality during my visits to collect data.

The investigations were continued while I was working in the Orthopaedic Department run by the Society and Home for the Disabled in Odense. Thanks are due to my chiefs in that Department, K. Harry Sørensen, M.D., and Å. Randløv, for their interest and for the access to that part of the Thomas caliper series which had been treated in Odense. The normal material too was collected in Odense.

During my appointment as research assistant to the Anatomy Department of the Odense University I had ideal working conditions for combining and writing up all the data. I am thankful to Professor F. Bierring, Head of the Department, who also took an intense interest in the investigation of the vascularization of child hips which I carried out during that period. My thanks are due also

to members of the Department staff who rendered help in various ways and took part in the studies.

For careful typing of the book I would like to thank Jonna Madsen, medical secretary. The statistical calculations were performed by H. K. Kvist, M.Sc., to whom I am indebted for incredibly speedy help in a part of the study which I had no possibilities of solving myself.

Last, but not least, I want to thank my wife, Hanne, for her great practical help, at many late hours, in recording the numerous data on punch cards (Karlo Hansen system), and for her enormous patience during all the years that this study took so much of the spare time which I ought to have spent with my family. It is, therefore, a great pleasure to dedicate this book to my wife and children.

Århus, January 1975

Jørgen Lauritzen

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OBJECT OF THE STUDY

I: To review the literature with the main emphasis on:

(a) what has been published regarding Legg-Calvé-Perthes disease since 1960,

(b) ascertaining the long-term prognosis of the disease,

(c) being able to discuss aetiological hypotheses in the light of other types of epiphyseal necroses affecting the femoral head.

II: To describe an out-patient treatment method by which the patients are relieved of weightbearing sitting in a wheel chair, and

(a) investigate how this therapeutic method can be practised in relation to the patient's home situation,

(b) analyse the primary healing results.

III: To investigate the true value of analysing the result by measurements on X-ray films

(a) by assessing the accuracy of the measurement

(b) by comparing the results of two different investigators by cross-control measuring.

IV: To assess, by means of prognostically relevant grouping, a very large case material with a view to the influence of the following factors upon the result:

(a) patient's sex

(b) age at institution of treatment

(c) radiological stage at institution of treatment

(d) degree of epiphyseal changes on the X-ray film

(e) degree of relief from weightbearing assessed for different methods of treatment.

CHAPTER 1

INTRODUCTION ON LEGG-CALVÉ-PERTHES DISEASE

PRIMARY HISTORY OF THE DISEASE:

Discovery:

In June 1909 a young surgeon, Arthur T. Legg, read a paper to the American Orthopedic Association about 5 children suffering from a special hip disease. On 17.2.1910 he published his findings accompanied by X-ray films of four of the patients. His description, and especially his discussion of the disease entity was extremely lucid and logical. He suggested traumatic, avascular epiphyseal necrosis as a possible explanation of the changes observed in children aged 5 - 8 years who limped, but presented scanty clinical changes.

On 10.7.1910 the Frenchman Jacques Calvé gave a thorough clinical and radiological description of the same disease. He had found 10 patients among 500 having hip pain. The age range was from 3½ to 10 years. Two of the patients were siblings. Calvé realized that he was dealing with a disease sui generis.

In October of the same year the German professor Georg Perthes (1910) described the same disease in 6 patients. He interpreted it as juvenile osteoarthritis and did not recognize until 3 years later in a more detailed paper on 21 patients (Perthes 1913), in which he referred to Calvé, that this was a separate disease entity of familial occurrence.

As early as 1909 the Swede Henning Waldenström had described the same disease, but interpreted it as a special type of juvenile tuberculosis of the hip.

Name:

The disease did not at first receive any official name. Michelsen (1914), in Denmark, suggested that as a suitable honour the disease be provisionally called Calvé-Perthes disease, and as such it is still commonly known in Denmark, presumably because Møller (1926) passed this name on. Michelsen did not refer to Legg whose paper he probably did not know, possibly because in those times Danish medical science was more oriented towards literature in German than in English. This is perhaps the explanation why Legg's name has never got further than on a level with the other two. Recent linguistic rationalization, especially in Anglo-Saxon literature, has shown a tendency to omit two of the names, calling the condition merely Perthes disease. Thus, the honour which Michelsen wanted to confer has eventually fallen to the wrong man.

In searching the literature, a number of guide words have to be employed apart from the names of Legg, Calvé, and Perthes, as the libraries and the great international journals have not yet standardized their index term for the disease. Most often, it is still recorded under its original designation: osteochondritis juvenilis coxae.

The present author has chosen the designation Legg-Calvé-Perthes disease (LCPD).

INCIDENCE:

The disease is fairly rare, but there is a marked racial difference (Goff 1954), apparently with a preponderance in the white race. In Denmark Mose (1964) found an incidence of 0.9 - 1.0 per 1000 live born infants. Molloy & MacMahon (1966), in a study among the population of Massachusetts, found an incidence in the white population of 0.816 per 1000, distributed by 1.35 in 1000 boys and 0.27 in 1000 girls. Among Broder's (1953) 102 patients only 7 were Negroes, although the population served by the hospital was mainly of Negro origin. However, there has been no real incidence study in races other than the white.

CLINICAL FEATURES:

The most important clinical aspects of the disease had been mentioned in the very first reports. The first major study (Sundt) saw the light of day in 1920, and since that time there have been no important additions. The disease arises during childhood, between the 2nd and 12th year of life, but with an age peak from the 6th to the 8th year. Boys are affected about four times as often as girls, the right and left hip with almost equal frequency, but in about 10% both hips are involved. There is a pronounced familial accumulation, and traumas are often adduced as having initiated the symptoms.

By far the most outstanding sign is a limp which, however, does not seem to trouble the child much. Occasionally the patients complain of pain in the hip, thigh, or knee, they tire quickly, and often find it difficult to keep up with mates of their own age when running and playing. The symptoms are so far from alarming, that often a long time may elapse before a doctor is consulted.

On physical examination the main finding is restricted mobility in the hip joint, especially in abduction and internal rotation. There is also mild atrophy of the femoral muscles.

RADIOLOGY:

A child with a limp should always have his hips examined by radiography which is the best method for establishing the diagnosis. The disease runs a characteristic and thoroughly investigated radiological course which Waldenström (1923) divided into several stages. It is important to know the early X-ray signs, and in his review of the disease Møller (1924) pointed out the value of Lauenstein's projection as well as the anteroposterior view. The classical radiographic findings have most recently been summed up in a major review by Edgren (1965). Waldenström (1934) mentioned, as an important early sign in the anteroposterior view, an increased width of joint space medially from the head of the femur to the so-called "Köhler tear drop" and on the Lauenstein film a subchondral linear translucency in the anterior part of the epiphysis. Eyring et al. (1965) confirmed that the width of the joint space medially is increased by more than 1 mm as compared with the good side in 70% of early LCPD patients, whereas 96% of 1000 normal hips showed a difference of less than 1 mm. As stated by Caffey (1968), the widened joint space is due to a diminished epiphysis.

An increased density of the femoral head epiphysis has been mentioned as a characteristic sign during the initial stage. In densitometric studies Bohr (1971) found that initially the radiodensity of the epiphysis was the same on both sides. The epiphyseal sclerosis is only relative, due to decalcification of the surrounding bony tissue. Brailsford (1948) related the relatively increased density of avascular necrotic bone to lacking decalcification. The surrounding decalcification is presumably due to increased blood flow in the region, as Bessler (1969) found, by autoradiography and scintigraphy, that this is the usual reaction of living bone to necrotic foci. As causes of truly increased sclerosis he mentioned either (1) local storing of calcium, (2) compression of necrotic parts of spongy bone or (3) newformation of bone on dead trabeculae.

After relative sclerosis and a subchondral translucent line (Fig. 1) the epiphysis starts flattening anteriorly. This is followed by increasing general flattening with true epiphyseal sclerosis. This appearance (Fig. 2) should no longer be interpreted as the initial stage.

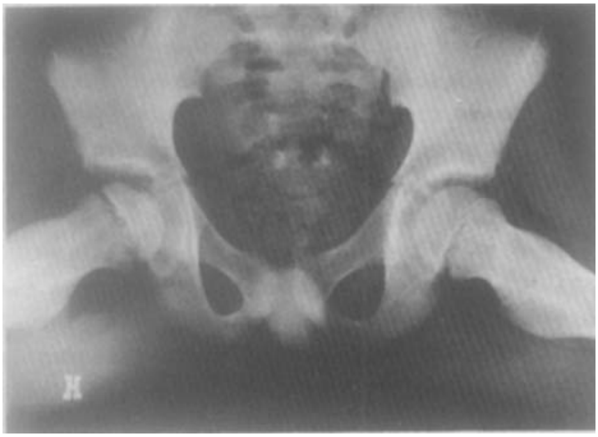

Fig. 1: Early stage. Distinct subchondral line in the anterior part of the epiphysis. Relative sclerosis in the remainder of the epiphysis (Case 2).

Fig. 2: Epiphysis condensed and flattened. Epiphyseal line wide and translucent towards the metaphysis. Greatly advanced stage (Case 41).

Otto (1968) considered this as compressed broken trabeculae. At this stage there are often changes in the epiphyseal line, which is more irregular and wider than on the good side. There appear also more distinct metaphyseal changes, with a more pronounced decalcification in the area adjoining the epiphyseal line, possibly with cyst-like translucencies. Gill (1940) even considered these metaphyseal changes as being primary and the epiphyseal changes secondary.

After, or perhaps simultaneously with, the condensation and flattening of the epiphysis, its structure starts breaking up into the so-called fragmentation (Fig. 3). Even though the film now apparently shows an irregularly flattened epiphysis, the shape of the femoral head is in fact not much changed. Arthrography using iodized contrast medium (Jonsäter 1953 and Katz 1968), injection of CO_2 into the joint (Koch 1969), as well as operations on the joint (Haythorn 1949, Cathro & Kirkaldy-Willis 1963, Larsen & Reimann 1973) have shown the cartilage-lined head to be considerably closer to spherical shape than the shadow of the bone might lead one to assume. By measurements on arthrographies Axer & Schiller (1972), however, found only one of 19 heads to be spherical, the remainder being flattened laterally and the majority also anteriorly.

Fig. 3: Example of subtotal fragmentation. (Case 83).

The fragmentation, which always occurs, may comprise a varying part of the epiphysis. Ponseti & Cotton (1961) divided it into three degrees, with different rate of course and different therapeutic result. A change in structure throughout the epiphysis was found in only one-sixth of their patients. The severity of epiphyseal and metaphyseal changes is parallel. At a time, which may be extremely difficult to fix with accuracy, the X-ray appearances show signs of increased reconstruction of the bony structure. In a radiographic study of 200 patients Simril (1961) maintained that he had seen no case in which the fragmentation increased anew, once the improvement in epiphyseal structure had begun. The structure gradually improves, until it has returned to normal at the time of primary healing. At that time the head has attained a shape which may vary between severely flattened, irregular, and normal spherical shape. This shape is largely maintained ever after. The long-term prognosis of the disease depends upon whether or not the head attains spherical shape. In rare cases the healing leaves osteochondritis dissecans, but according to Ratliff (1967) this is of no clinical importance, judging by two cases followed through 30 years. However, Morris & McGibbon (1962) have reported one such case in which the osteochondritis fragment loosened.

LABORATORY FINDINGS:

In the literature on LCPD from the first 30-40 years the various authors did not succeed in demonstrating any laboratory findings that were abnormal or could otherwise be called definitely characteristic of LCPD. More recently Schönenberger et al. (1962) and Hirthe & Mühlbach (1966) have found slightly increased excretion of taurine in a number of LCPD patients in studies of the urinary excretion of amino acids, but this has not yet led to any diagnostic or therapeutic consequences.

CHAPTER 2

ANATOMY OF THE HIP JOINT DURING CHILDHOOD

TOPOGRAPHY:

LCPD affects that part of the upper femoral end which is situated within the capsule of the hip joint. It, therefore, seems appropriate to describe the anatomy of the hip joint during childhood in some detail.

The femoral head constitutes about two-thirds of a sphere lined with hyaline cartilage except at the site of the fovea which contains fibrous connective tissue. The articular surface in the acetabulum is a large segment of a hemispherical cup in which the incisura acetabuli is not lined with cartilage but filled with fatty tissue. The transverse acetabular ligament spans the incisure, and the acetabular lip supplements the articular socket the rest of the way.

The fibrous capsule extends from the external aspect of the acetabular lip and the transverse ligament to the femoral neck, where it is solidly anchored in the orbicular zone which is highly developed during childhood. The capsule attaches loosely to the bone anteriorly and medially at the site of the intertrochanteric line, posteriorly and laterally at the middle of the femoral neck. The capsule fibres and the fortifying iliofemoral, ischiofemoral, and pubofemoral capsular ligaments run a tortuous course in pronation.

In direct relation to the capsule the iliopsoas muscle pronates antero-medially, whereas the external obturator muscle courses laterally across the posterior aspect of the joint capsule. Both muscles effect external rotation of the joint; moreover the iliopsoas flexes and the external obturator adduces.

When the hip joint is extended, the capsule, ligaments, and muscles tighten, and the tightening effect is increased in internal rotation and abduction. When the joint is flexed all these structures relax completely, as they do also to some degree in adduction and external rotation. On flexion in the joint the femoral head is, moreover, much better covered by the acetabulum than in an extended position during which its entire anterior half is uncovered.

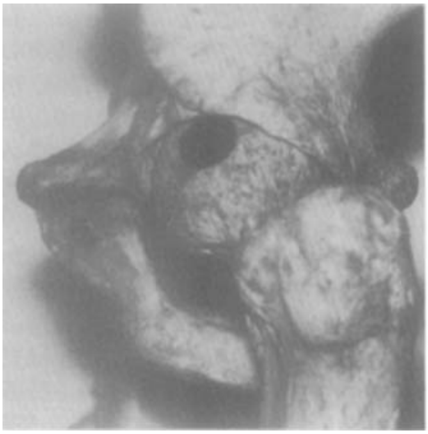

Fig 4: Situation of the femoral head in the acetabulum when the hip joint is extended. The anterolateral area, where LCPD starts, is marked.

Fig. 5: The femoral head enters the acetabulum, when the hip is flexed. The anterolateral area is almost totally covered (arrow).

From the transverse acetabular ligament the ligament of the femoral head courses to the fovea. This ligament and the fat pad in the acetabular fossa are intracapsular, but extrasynovial. The synovial capsule extends from the cartilaginous border on the head to the acetabular lip along the inside of the fibrous capsule. This forms a synovial fold around the femoral neck, most pronounced medially and anteriorly where the capsular attachment is farthest from the cartilaginous border.

GROWTH OF THE PROXIMAL END OF THE FEMUR:

The intracapsular part of the upper femoral end consists of the epiphysis and the metaphysis, which are separated by the epiphyseal cartilage and a small part of the diaphysis. The epiphyseal ossification centre forms when the infants are 4 - 8 months of age. The epiphyseal ossification centre grows predominantly along the periphery, at the transition to the articular cartilage, in the basal part of which calcium is deposited, and osteogenesis takes place beneath this site. Throughout childhood the epiphyseal plate makes the epiphysis an isolated bony island surrounded by cartilage except in the foveal area.

Metaphyseal growth takes place from the basal part of the epiphyseal plate, along the lateral edge of the femoral neck, and from the basal aspect of the epiphyseal plate of the greater trochanter. Growth in the upper end of the femur has been studied in rat foetuses (Lütken 1947) and in pigs and rabbits (Salenius & Videman 1970).

At birth the femoral neck is very short. The head is in a valgus position and anteverted. During childhood the inclination as well as declination angles diminish most rapidly during the first 2 years of life (Glogowski 1962, Shands & Steele 1958). The latter authors found the neck to be more anteverted in girls than in boys. Among 34 LCPD patients they found only 6 to be anteverted by more than 10° above average. This agrees with Katz (1968), but is at variance with Craig et al. (1963) who found LCPD to occur always in hips with considerably increased anteversion. The shape and inclination of the pelvis also shows sex differences during childhood, apart from being dependent on genetic factors (Gardner et al. 1969).

VASCULAR SUPPLY OF THE HIP JOINT IN CHILDREN:

The studies of Wolcott (1943),Tucker (1949), Trueta (1957), Harty (1953, 1966), Hipp (1962), Crock (1967), Müssbichler (1970), and Lauritzen (1974) seem to have established the vascular supply of the femoral head and the variations in the course of the vessels during childhood.

The deep branch of the medial femoral circumflex artery runs behind the femoral neck, between the quadratus femoris and the external obturator muscles, ending laterally on the neck, where it perforates the capsular attachment as rami nutricii capitis proximalis coursing deep to the synovial membrane up along the neck as retinacular vessels. These vessels penetrate the cartilage at the junction of the epiphyseal plate and cartilage surface, whereupon they enter the epiphysis, after having given off branches to the metaphysis.

From the deep branch, vessels in the form of rami nutricii capitis distalis perforate the capsular attachment postero-medially and course in a subsynovial situation up along the neck as retinacular vessels. After giving off branches to the metaphysis, the vessels penetrate the edge of the epiphyseal cartilage and enter the epiphysis. On the anterior aspect of the joint similar branches, derived from the lateral femoral circumflex artery, course as rami nutricii capitis anteriores along the neck in a subsynovial situation to the anterior aspect of the metaphysis and epiphysis. From the acetabular artery a branch, the arteria ligamenti capitis femoris, accompanies the ligament to the fovea.

Before the epiphyseal centre has been formed, the head consists of a cartilaginous sphere on a short, broad neck. A few vessels, mainly from the distal aspect, enter this sphere. The process of ossification begins around these vessels in the centre of the sphere. Gradually as the epiphyseal centre grows, these afferent vessels assume a more peripheral position through the epiphyseal cartilage. During the next couple of years the epiphysis is supplied almost equally from the three sets of branches, proximal-lateral, distal-medial, and anterior.

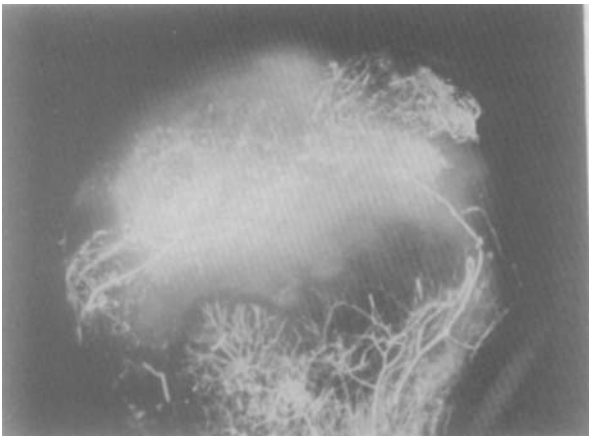

Fig. 6: Injection of Microphil R and clearing by the method of Spalteholz in the normal femoral head of a child aged 3 years 10 months, viewed from the posterior aspect. The epiphyseal vessels fill from 3 proximal nutrient branches and one distal nutrient branch. Foveal vessels superiorly on the right.

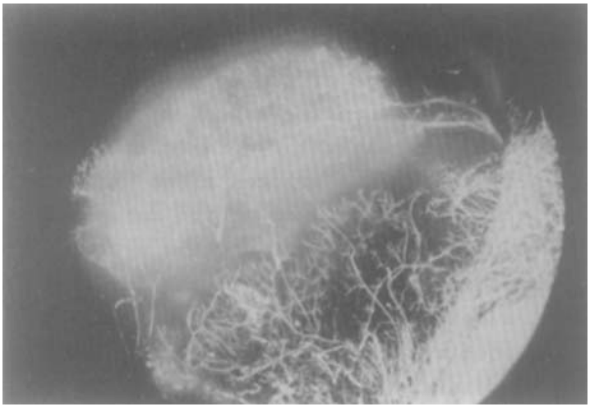

Fig. 7: Same specimen as in Fig. 6, viewed from the anterior aspect, where 5 thin anterior nutrient branches enter the epiphysis.

Throughout childhood, the arteria ligamenti capitis femoris supplies in the main the ligament, the connective tissue in the fovea, and the synovial membrane around the ligament, but also has delicate anastomoses with the epiphyseal vascular network. However, these anastomoses are probably not of decisive importance in epiphyseal nutrition (Schülz 1971).

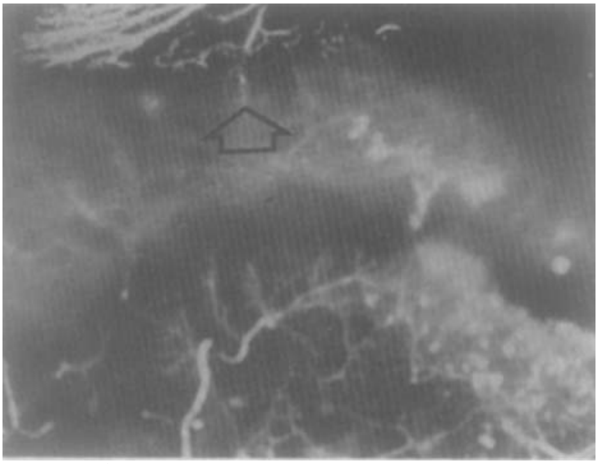

Fig. 8: Same technique as in Fig. 6, in a normal child aged 6 years 3 months. The vessels in the fovea are seen "floating" above the epiphysis, with one small anastomosis entering it (arrow).

According to Trueta (1959, 1960) these anastomoses are more constant in Negro children than in the white race. At the age of 4 - 6 years first the anterior and then the distal retinacular arteries stop running into the epiphysis. Until the epiphyseal cartilage starts closing, and thus no longer forms a barrier to anastomoses between the metaphyseal and the epiphyseal vascular network, the epiphysis is increasingly dependent on a normal function of the deep branch of the medial circumflex femoral artery and its final twigs.

The distribution of the vessels in the epiphysis, especially during the critical age interval, does not appear to have been the subject of thorough studies. However, it has been demonstrated by Trueta & Morgan, Trueta & Little, and Trueta & Amato (1960), in histological, electron microscopic, and experimental studies on the vascular contribution to osteogenesis in animals, that a tortuous vascular network forms in the basal part of the epiphysis, between the condensation line and the growth cartilage. The cartilage is nourished by the vessels in the epiphysis. From the metaphysis vessels force their way, densely and brush-like, in between the cartilage columns, and endochondral osteogenesis is dependent upon this vascularization. Wolcott (1943) published photographs taken from the lateral aspect, and judging by these photos the vascular network appears to be less dense in the anterior part of the epiphysis, an appearance which was confirmed by Lauritzen (1974). The venous discharge does not seem to have been studied in any detail in children, but the veins apparently accompany the arteries.

INNERVATION OF THE HIP JOINT:

This has been studied by Gardner (1948), Larochelle (1949), Kaiser (1949), and Wertheimer (1952), and may be summed up as follows:

The joint receives branches from the obturator nerve, from the sacral plexus, and from the femoral nerve. The obturator branch appears to be the most important one. As a rule it departs before the bifurcation of the obturator nerve in the obturator canal, or a short distance after the bifurcation, and if so most often from the anterior branch. The entrance of the nerves into the joint is medially through the external obturator muscle and the pubocapsular ligament or deep to the transverse acetabular ligament. The obturator branch seems to constitute the main innervation of the anterior two-thirds of the joint. Incidentally, the obturator nerve supplies the adductor muscles, and the branch to the external obturator muscle departs either from the main stem or from the posterior branch. The obturator nerve often sends sensory branches down to the medial aspect of the knee joint.

Innervation of the posterior aspect of the joint is from the sacral plexus or from the sciatic nerve, as a rule via the musculo-articular nerve which innervates also the quadratus femoris muscle, often the inferior gemellus muscle, and sometimes the internal obturator muscle. Some uncertainty prevails concerning the innervation from the femoral nerve. In a special study of this component, Wertheimer found that it never reached the joint itself, only the vessels. It might be imagined that the autonomic nerves to the joint would course this way, corresponding to the vascular supply by the branches of the femoral artery, whereas the cerebro-spinal nerves would accompany the other two nerve stems.

CHAPTER 3

MICROSCOPIC FINDINGS IN EPIPHYSEAL NECROSIS IN THE FEMORAL HEAD

PATHOLOGY IN LCPD:

Only a few authors have had the occasion to study the morphological changes in the entire affected femoral head. Zemansky (1928) reviewed 11 cases and added one of his own. At that time, most studies were based upon femoral heads removed by operation, but a few were from autopsies. Since then Gall & Bennett (1942) and Dolmann & Bell (1973) have described one autopsy case each and Jensen & Lauritzen (1974) two autopsy cases. Since resection of the femoral head as a treatment has been abandoned long ago, such studies of the total affected head will be extremely rare in the future and can be based solely on deaths among children suffering from active LCPD.

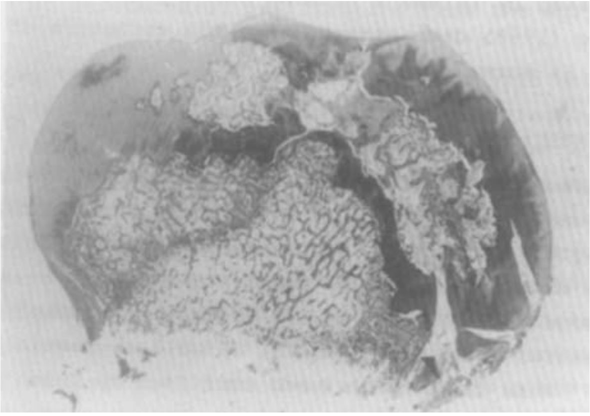

Fig. 9: Cross section of the left femoral head in LCPD. The patient died at the age of 4 years 10 months, when the disease was in the phase of healing.

The investigations have shown consistently that the articular cartilage is normal, or perhaps shows faint signs of degeneration basally. The epiphysis is the seat of severe or total marrow necrosis, but otherwise consists of a mixture of areas showing necrotic bone, amply vascularized granulation tissue, and cartilage islets. New-formed bone may be observed as "creeping apposition". In some cases the epiphyseal plate is totally degenerated, in others near-normal. The vessels appear to be normal.

These findings have been confirmed by a number of other authors who have taken biopsies, most often when drilling through the femoral neck. The most comprehensive and most systematic study on biopsies is the one by Jonsäter (1953) who linked the radiological stages up with histological differences. In the early stages he found, like Haythorn (1949), that the necrotic bony tissue might have broken down and got compressed. In sites where the bony necrosis was adjacent to the cartilage border, the basal part of the cartilage may be degenerated. At the stage of fragmentation the tissue was more vital, showing incipient bone formation, which increased through the stage of repair. According to Exner (1968) the histological appearances differ widely from those in posttraumatic epiphyseal necroses. Mattner (1968) observed bone formation as "creeping apposition" even in the early stage, and this has been observed also by Larsen & Reimann (1973). By a radiological study Münzenberg (1968) demonstrated that the structure of collagen in the epiphysis is normal in LCPD.

ANIMAL CONDITIONS SIMILAR TO LCPD:

Thomasen (1939), studying the head of the humerus in 1482 pig bones, found 4% with grossly flattened head, a wrinkled surface of the articular cartilage, and microscopic changes in part of the epiphysis exactly similar to those in LCPD.

In dogs Moltzen-Nielsen (1938) has found epiphyseal necrosis in the femoral head with skeletal as well as partial cartilaginous necrosis. This finding has been confirmed by Hulth et al. (1962), while Ljunggren (1967) found this process to start in miniature dogs as increased endosteal growth of bone, whereby the trabeculae thickened prior to incipient necrosis. She believed that the aetiology was hormonal, but did not rule out (Ljunggren 1969) that the blood supply might play a certain role. According to Ljunggren, Rütt & v. Schmoller (1969) tried to induce the changes by administering chorionic gonadotropins, but did not succeed when using rabbits or large dogs as experimental animals.

From a study of gorilla skeletons, Taylor et al. (1955) deduced that these animals might also suffer from an LCPD-like disease.

EXPERIMENTAL EPIPHYSEAL NECROSES IN ANIMALS:

Many authors have performed animal experiments and studied the behavior of the epiphyses in connection with avascular ischaemia.

Bentzon (1926) and Randløv-Madsen (1950), injecting alcohol around the femoral neck in rabbits, believed they had induced LCPD-like epiphyseal changes. Miltner & Hu (1933) did not obtain this result until they supplemented the alcohol injection with removal of the periosteum around the femoral neck in their experimental animals.

Harris & Hobson (1956), after traumatic epiphysiolysis on the femoral heads of rabbits, very soon observed necrosis in the epiphysis which collapsed before regeneration was completed. They found only mild changes in the articular cartilage. The same experiment on the epiphyseal disc of the distal end of the radius (Dale & Harris 1958) does not induce epiphyseal necrosis, as it does not tear all the vessels to this epiphysis, but it causes the same transient interruption of endochondral ossification from the epiphyseal cartilage.

Following traumatic dislocation of rabbit hips Bohr et al. (1965 and 1968) studied the results by radiology, microradiography, and microscopy, by the conventional technique as well as by fluorescence after labelling with tetracycline. They observed changes very similar to LCPD, int. al. temporary invasion of vessels from the metaphysis through the epiphyseal cartilage. Such vascular invasion into an avascular epiphysis was observed by Young (1966) in an experiment in which he used the epiphysis of the metatarsal head in rabbit young. Medgyesi (1971), after pedicled revascularization of the sawn-off femoral head from the trochanter or a muscle, found the epiphyseal cartilage plate to form an absolute barrier to vascular invasion. If the vascularized pedicle was brought into direct contact with the epiphysis, a slow process of re-ossification followed upon the primary necrosis, but bone formation occurred last in the most remote parts of the epiphysis. The articular cartilage was not described.

Slätis & Rokkanen (1966) induced epiphyseal necrosis by subcapital osteotomy on rabbits. They observed collapse of trabeculae during the first stages and also observed the regeneration to be progressing slowly from the metaphysis and outwards. The cartilage and the most adjacent part of the bone did not undergo necrosis, and this site was the only one to retain the tetracycline labelling one week later, a sign of nutrition from the synovial fluid. Lemoine (1957) demonstrated that the vascular supply of the femoral-head epiphysis in rabbits is somewhat different from that in man. However, the differences do not appear to be too marked for rabbit experiments to reproduce the human changes quite well.

Salter (1966) induced necrosis of the femoral head in pigs by ligation around the neck. Bone growth was arrested, but not cartilage growth. Thus, it appears that the articular cartilage remains vital, due to some nutrition received from the synovial fluid. Indeed, Mankin (1962) found that tritium-labelled thymidine injected into rabbit knee joints was recovered partly in the most superficial layer of the cartilage and partly at the junction to bone, at the two sites where cartilage activity is at a maximum. That the articular cartilage is also dependent upon the vascularization in the underlying bone was demonstrated by McKibbin & Holdsworth (1966) in an elegant experiment on young lambs. In their experiment the basal part of the cartilage and the osteogenesis proved to be dependent especially upon the vascularization of the bone, also related to time, but the tissue was reactivated after revascularization. In a rabbit experiment, Young (1966) demonstrated how the epiphyseal cartilage plate depends upon epiphyseal vascularization, whereas osteogenesis on the metaphyseal side depends upon the metaphyseal vessels.

CHAPTER 4

RELATION TO OTHER DISEASES

CONGENITAL DISLOCATION OF THE HIP:

It is beyond doubt that epiphyseal changes of the type seen in LCPD will occur in a considerable number of those children in whom congenital dislocation of the hip is not diagnosed and treated at birth and who are presented for reduction later. This was described by Legg as early as 1927. Massie (1951) found these LCPD-like changes to be far more common in boys, although dislocations occur more often in girls. Meyer (1964) pointed out that the epiphyseal changes in congenital dislocation of the hip belong to the type which he calls epiphyseal dysplasia of the femoral head. He found a familial relation between these two conditions and LCPD.

As to the frequency of such changes there is great disagreement. Dooley (1963) has reported 50%, Limbers (1965) 16 - 20%, and Illyés only 6.7%. In a series of 627 patients treated for congenital dysplasia or dislocation of the hip, Tönnis & Kuhlmann (1969) found the frequency among all 1254 hips to increase appreciably with age. Epiphyseal necrosis occurred in 10.3% of those treated during the 1st year of life, in 47.2% treated during the second year, and in 62.3% treated during the 3rd year. Regardless of age, only one-fifth developed changes of a severity which involved distinct flattening of the epiphysis. The increasing frequency with age among all the hips indicates a relationship to the abduction treatment given, rather than to the dysplastic hip, and is compatible with a vascular explanation based on the anatomical relations. This has been confirmed by the angiographic studies of Nicholson et al. (1954).

In German literature these epiphyseal changes are often termed "Luxationsperthes", int. al. by Schulz (1971) who found them to be far more common following open reduction plus derotation osteotomy than following open reduction alone. The patients most liable to these changes were those treated conservatively before the operation.

TRANSIENT SYNOVITIS IN THE HIP JOINT:

Among 46 patients with transient synovitis in the hip joint Spock (1959) reported subsequent LCPD changes in 3. Hardinge (1970) found no aetiological explanation of transient synovitis in the hip. Like LCPD, this disease is most common among boys aged 5 - 9 years, and both sides are equally often affected. The complaints are scanty, but the limitation of motion more diffuse. According to Valderama (1963), Adams (1963), and Gledhill & McIntyre (1969) there seems to be no relationship between this benign, short-lasting disease and LCPD. Emr (1966), on the other hand, believes there is. Calculating the epiphyseal index on both hips, he found a number of LCPD patients to have inferior epiphyses. This applied particularly to the youngest patients in whom the condition is most often bilateral. In this constitutionally hereditary group he feels that synovitis is a factor in the development of LCPD, the flatter epiphysis being more apt to cause obstruction of the vessels. In consequence, he treats patients with synovitis and flat epiphyses with non-weightbearing for 3 months. In contradistinction to this group, he found that LCPD children with a history of trauma were older and always had normally developed epiphyses, when the disease started, and in these cases the condition was never bilateral. In this way he tried to unravel the aetiological factors in LCPD.

Stillman (1966) felt that LCPD and osteochondritis dissecans were of the same genesis, LCPD arising in cases of a specific, multifacetted constitutional disturbance, occasionally with an inherited familial predisposition and elicited by trauma or stress to the hip.

DELAYED SKELETAL MATURATION:

The oft-mentioned constitutional factor has been interpreted as delayed growth and skeletal maturation in relation to chronological age. Haythorn (1949), Mau & Schmitt (1960), Ralston (1961), Ponseti & Cotton (1961) as well as Fischer (1972) have reported that in LCPD children bone age is delayed by a year or two. Molloy & MacMahon (1967) found LCPD patients to have a lower birth weight than a control group.

ENDOCHONDRAL DYSOSTOSES:

Owing to the familial tendency and the localization in the epiphysis, it is reasonable to imagine that LCPD is related to the various diseases involving a disturbance of endochondral osteogenesis. Mau (1958) imagined that such disturbances might possibly constitute the endogenous component of LCPD, the vessels to the epiphysis being more easily obstructed when the cartilage was of poor quality. The epiphyses of the hip are nearly always involved in Morquio's disease (Robinow 1958) and in what Fairbank (1945) called multiple epiphyseal dysplasia. The similarities, and especially the differences, between these dysplasias and LCPD have been discussed by Weinberg et al. (1960), Rubin (1965), and Kozlowski & Lippska (1967). Jacobs (1968) pointed out that long-lasting non-weightbearing is of no value in multiple epiphyseal dysplasia as it is in LCPD.

Trias & Ray (1963) have described a boy with LCPD who one year later developed aseptic necrosis of both radial heads. Studying the X-ray films of 120 patients with LCPD, Hübner (1968) found a higher than normal frequency of delayed synostosis between the ramus ischii and the ramus inferior ossis pubis (van Neck's disease). This he interpreted as a sign that LCPD was due to a generalized disturbance of ossification.

OTHER AVASCULAR EPIPHYSEAL NECROSES IN THE FEMORAL HEAD:

Atraumatic:

Gaucher's disease may be accompanied by epiphyseal necroses, int. al, in the femoral head. Arkin & Schein (1948) believed that this was due to perivascular accumulation of Gaucher cells, and according to Katz (1967) the condition may recur after primary treatment and improvement, something which does not happen in LCPD.

In Negro children, in whom LCPD is extremely rare, epiphyseal necrosis may occur in the presence of sickle-cell anaemia. Golding et al. (1959) found no metaphyseal changes in these cases. Chung & Ralston (1969) reported an LCPD-like course in 6 out of 13 patients. The cause of the necrosis is said to be microthrombi of the abnormal blood cells, elicited by reduced oxygen tension.

An entirely new phenomenon is aseptic epiphyseal necrosis following renal transplantations. This was found by Cruess et al. (1968) in 10 out of 27 patients who survived longer than 6 months. In these cases too the femoral head epiphysis was the one most often involved. The articular cartilage was normal. That these necroses are attributable to the cortisone medication seems to be more evident now that Harrington et al. (1971) have demonstrated that their occurence is dependent upon the dose of cortisone. Rodegerdts (1969) found necrosis of the femoral head in a 12-yearold girl who had been on long-term cortisone thepapy for ulcerative colitis. By angiography he demonstrated occlusion of the distal vessels to the head as well as narrowing of the deep branch. He presumed that cortisone altered the coagulability of the blood. Markheim (1949) has reported the case of a patient with unilateral LCPD who 2½ years later exhibited epiphysiolysis in the contralateral femoral head. The same applies to Case 121 of the present material.

Traumatic:

Traumatic dislocation of the hip in children is sometimes followed by necrosis of the femoral head. This has been reported by Quist Hansen (1945) in 1 out of 8, by Piggot (1961) in 1 out of 9, and also by Haliburton et al. (1961) in one case in which the condition soon returned to normal. Glass & Powell (1961) have reported that among the 25 cases on record from 1927 to 1958, 6 developed necrosis. In their own series of 47 cases 4 developed necrosis and 3 degenerative changes in the joint. Hipp (1969) found a much higher frequency, viz. 5 total and one partial necrosis out of 10 dislocations, and among 40 children with fracture of the femoral neck he found 17 to develop total and 3 partial necrosis. By arteriography he demonstrated that sometimes the vessels to the epiphysis merely get obstructed, but open up again if reduction is carried out immediately.

Although a fracture of the femoral neck is extremely uncommon in children, there have been many reports. Nielsen (1938) described 3, Carrell & Carrell (1941) 12, Allende & Lezama (1951) 8, Ingram & Bachynski (1953) 24, Durbin (1959) 3, and McDougall (1961) 24. Ratliff (1962) had seen 19 and reviewed 52 treated elsewhere, so that his material comprises 71 patients, 30 of whom developed necrosis. Lam (1971) found only 17% with necrosis among his 75 cases. Summing up, it may be said that necrosis occurs very often when the fracture is transcervical or subcapital, and when it is displaced. The necrosis may involve the entire proximal fragment; in that event it leads to total epiphyseal collapse, and the end result will be poor. However, partial epiphyseal necrosis or isolated metaphyseal necrosis may occur, and in such cases the prognosis is considerably better. The course and result may be explained simply on the basis of the vascular supply to the upper end of the femur.

In epiphyseolysis without trauma epiphyseal necrosis is also common, but as a rule it is partial. Rütner (1954), Lowe (1961 and 1970) and Maurer & Larsen (1970) agree that cartilaginous necrosis is a more common finding than bony necrosis and of much more prognostic importance. Salter & Harris (1963) as well as Ratliff (1968) found that traumatic epiphyseolysis in the femoral head was a very serious disease with a high risk of total epiphyseal necrosis and permanent deformation of the joint.

OTHER DISEASES NOT AFFECTING THE FEMORAL HEAD:

From 178 LCPD patients and 89 control patients Katz (1959) deduced that LCPD bore no definite relation to occult spina bifida.

Catterall et al. (1971) made a systematic study of 282 patients and their families. They found a surprisingly high frequency of various urinary tract anomalies plus 8 times the expected number of inguinal hernias among the 229 boys. They suggested that anomaly of the development of the vessels in the hip might be an aetiological factor when combined with changes in the urogenital primordia. In cases with developmental anomalies following thalidomide Stainsby & Quibell (1967) found LCPD changes in two such children. However, one of them had previously been treated with a Dennis-Browne splint for subluxation of the hip.

AETIOLOGICAL THEORY:

Owing to the infinitesimal information about the pathological changes in other forms of epiphyseal necroses in children, deductions have to be made from the clinical and radiological prognosis of the various diseases, compared with the findings in adults.

Merle d'Aubigné (1964) as well as Patterson et al. (1964) found the articular cartilage to be normal in idiopathic necrosis of the femoral head in adults. This is found also in cortisone-induced necrosis and is an invariable finding in LCPD. The necrosis is primarily of a subchondral localization. In medial fractures of the femoral neck in adults Hulth (1961) found cartilaginous necrosis whenever there was bony necrosis, and in 13 out of 21 angiographed patients Müssbichler (1970) found that the lateral epiphyseal artery (ramus nutricius capitis proximalis) never filled when filling of the deep branch was delayed. This finding confirms those of Lange & Hipp (1960) who demonstrated also that normally the lateral epiphyseal artery may be followed by angiography 1 cm into the epiphysis.

In his comprehensive arteriographic study Hipp (1962) found in patients with LCPD narrowing or total occlusion of the deep branch behind the middle of the femoral neck.

All findings indicate that the ischaemia which causes LCPD is considerably more moderate than it would be if the vessels to the epiphysis were occluded by trauma or by a thrombus. There must be a question of a much briefer obstruction of the vessels, as also hinted by Trueta & de Lima (1959). As causes they suggested either synovial inflammation or an effect of the small external rotators of the hip.

In my opinion the explanation lies on the most peripheral part of the deep branch. Normally this artery runs just distal to the tendon of the external obturator muscle, curving superficially to the tendon towards the lateral part of the femoral neck, perforating the capsule, and proceeding subsynovially to the edge of the epiphysis where it penetrates the cartilage as several branches, just at the junction of the epiphyseal and articular cartilage, before inflecting about 60° and entering the epiphysis (Fig. 6 & 7, pp. 11 & 12).

If this artery has a genetically determined abnormal course, and perhaps runs deep to the tendon of the external obturator muscle, it will be squeezed against the femoral neck when the hip is in extension, and even more when it is in abduction and internal rotation. On the other hand, flexion, adduction, and external rotation leave free flow in the artery. The same motor pattern that tightens the tendon will tighten the joint capsule and thus will compress the artery in its course between the capsular fibres. Sex differences in the inclination and width of the pelvis may be operative. The arteries laterally on the femoral neck are well hidden and protected from traumas, but yet they may be injured by the acetabular margin during maximum abduction in the joint.

Due to periodical obstruction necrotization of the epiphysis will set in. The severity of this necrosis depends upon whether other arteries supplying the epiphysis, according to age and racial factors, are able to reduce the ischaemia. The highly undifferentiated bone-marrow cells necrotize first, and later this will affect endochondral osteogenesis which takes place mainly in a subchondral situation. An already inhibited or reduced endochondral osteogenesis is particularly liable to the changes. The osteogenetic changes occur first in the anterior part of the epiphysis which is the most peripheral one in its vascular network. Thereafter the necrosis will spread to already formed bony trabeculae. The nutrition of the epiphyseal cartilage plate will also be disturbed, but endochondral ossification will continue in the entire metaphysis, later even at an increased rate because of the subsequent hyperaemia. As the most resistant tissue, the articular cartilage will remain vital, int. al. because of the nutrition it receives from the synovial fluid. An adduction-external rotation spasm in the muscles of the hip is the most expedient, direct defence of the organism, as this reduces the tension on the deep branch. This spasm may give rise to mild pain, apart from of course entailing a limp. Flexion of the hip secures the best possible blood flow in the arteries supplying the epiphysis.

CHAPTER 5

TREATMENT OF LCPD

NON-WEIGHTBEARING:

In view of the uncertain aetiology of LCPD practically all authors suggest and recommend treatment on an empirical basis.

During the first 20 years after the disease had been describ-ed no special therapeutic principles were suggested. The literature from these years in fact gives an impression merely of pleasure at recognizing that the disease was not infectious, in particular not tuberculous, but a kind of inevitable juvenile destruction of the hip running a self-limiting course which caused the patient surprisingly little complaints, even years after healing (Sundt 1920, Waldenström 1923, Legg 1927). From the mid-30's interest in treatment by long-term non-weightbearing increased, and it was realized that thereby a considerably larger number obtained better primary healing of the femoral head (Danforth 1934, Eyre Brook 1936). This has been confirmed by all subsequent studies.

Since that time, any discussion has concerned the best method for non-weightbearing, the duration of non-weightbearing, and whether it might perhaps be supplemented by som other form of treat-ment that could further improve the results or at least shorten the course.

The most reliable method for relieving the diseased femoral head from pressure is to put the patient to bed with fixed legs under constant observation. The strictness with which this was carri-ed through in som clinics is apparent trom Pike's (1950) analysis of 59 children who had been tied to a frame in a hospital bed, around the clock, for periods ranging from 1 to 5 years. By this management excellent radiological results had been obtained.

Ferguson (1954) opposed such very rigid fixation. In his opinion it was essential that the hip could retain its mobility throughout, but it had to be spared any muscle traction. This he attained by traction in the longitudinal direction of the leg, with-out stating any time limits. Katz, who most recently analysed his results in 1967, still recommends bed rest + traction which he found to afford the most favourable results. This view is fully shared by

Meyer (1969) who reported no psychological strain on the children from a long stay in hospital. Lambert (1968), on the other hand, who derived his experience from teaching long-term orthopaedic paediatric patients, came up against certain psychological and paedagogic difficulties. Thompson & Bassett's experiments (1970) leave doubt as to the importance of treating the femoral head by total relief from weightbearing. By a histological study these authors found progressive signs of degeneration in the articular cartilage as well as in the underlying bone in rabbit knees treated by non-weightbearing.

Harrison et al. (1966, 1969) felt it was of great importance that the femoral head be fully contained within the acetabulum during the period of non-weightbearing, as the acetabulum was supposed to mould the head into spherical shape. In 1966 they found the best results after bed rest with the legs fixed in so-called broomstick plaster. In 1969, however, they had changed their views towards a preference for ambulatory treatment during which the leg was fixed, around the clock, for about 2 years in a specially designed leather brace. Tachdjian & Jouett (1968) described a similar, enormous bandage for ambulatory use. In an equally drastic manner, fixation of the hip has been consistently used for 17 years by Imhäuser (1970) as an ambulatory method. He fixed with plaster from mid-chest down to and including the affected foot, with the hip in 30^{o} abduction, 30^{o} flexion, and 30^{o} external rotation. Petríe & Bitenc (1971) have also used a large plaster bandage with the hips in 45^{o} abduction and in $5 - 10^{o}$ internal rotation through 19 months' ambulatory treatment, but the cast was changed every 3 or 4 months. Dethloff (1966) was content with plaster in inversion for a month or two, whereupon he changed to a gentler ambulatory treatment.

Most authors who recommend ambulatory treatment have used gentler methods. In 1947 Snyder described a sling for use in combination with ordinary crutches. This method has been used by Evans & Lloyd-Roberts (1958) and also partially in the present material.

By various forms of walking appliances the children are rendered independent of crutches. Wansbrough et al. (1959) used at Taylor splint, but most often ischial weight-bearing braces are used, e.g. the Thomas caliper which has been extensively used in Denmark, at least previously. The results have been reported by Reimann (1961) and Mose (1964), and patients treated by this means are also included in the present material. These walking appliances keep the hip in extension, which is not a particularly favourable position. Katz (1971) pointed out the importance of the moulding effect of the acetabulum upon the femoral head, when the latter is completely contained within the socket. Therefore, Cochhiarella et al. (1972) designed a removable brace which permits walking with the legs in 45^{o} abduction and 20^{o} internal rotation. The patients are allowed only one hour daily without the bandage.

No author seems to have dwelt on the time at which non-weightbearing should be started. Apparently, it is a presupposition that it should start as soon as the diagnosis has been established. The problem is, however, for how long the non-weightbearing is to be continued, and this must rest on a medical estimate. Herndon & Heyman (1952) reported a mean period of 17.2 months, discontinued when regeneration was well under way. Wilk (1965) recommended non-weightbearing for 3 - 4 years until the head has healed completely, but the necessity is doubted by Cumming (1967). Pappas (1967) took his guidance from the time when the surface contour had been reformed. According to Goff (1959, 1962) short-lasting relief from weightbearing gives equally good results as long-lasting, and he is now less afraid of allowing weightbearing at an early juncture. He has reduced his average non-weightbearing period to 9 months as compared with 19 months previously.

SUPPLEMENTARY TREATMENT:

Mere relief from weightbearing has to many seemed rather poor as the only therapeutic principle. In the course of time many other treatments of a more direct nature have been suggested as supplementary measures, mainly with the object of making the process run a more rapid course, so that the treatment period could be shortened.

During the past decade several suggestions have been advanced. Goff (1955) had given the preliminary statement that apparently he could shorten the course and the non-weightbearing period by administering aureomycin. In 1965 he confirmed, in a double-blind study on 54 patients, that tetracycline could significantly accelerate skeletal growth so much that he obtained quicker healing and moreover better results. No one seems to have had any inclination to test his ideas which do not appear to have gained ground elsewhere. The mechanism is perhaps by way of adrenocortical hormones, a route which has been tried also by Kristensen (1963) by a supplement of anabolic steroid. Ponseti & Cotton (1961) treated 22 patients with triiodothyronine. On comparison with 44 patients not thus treated they found no effect of the hormone therapy. This only confirms Gill's (1943) study in which he found no signs of impaired thyroid function in 20 LCPD patients.

Altav & Geimer (1967) tried to supplement by vasodilator agents in 14 patients and claimed that this accelerated healing. Berényi (1969) also wanted hyperaemia in the hip, which he obtained locally by injecting liver oil into the joint in 74 patients. He observed no side effects and felt that this could shorten the course by a year or two.

OPERATIVE TREATMENT:

In the course of time there have been numerous attempts at improving the results or hastening the course by operations on the hip.

Prior to 1930 operation was used only sporadically, but Bozsan (1932) recommended the use of drilling through the femoral neck, perforating the epiphyseal disc. In 1934 he described his technique in more detail, but pointed out the risk of premature epiphyseal closure. This method was used in 8 of the patients studied by Levy & Girard (1942).

Ferguson & Howorth (1934) reported that since 1928 they had used drilling up through the anterior aspect of the neck to the epiphysis in 15 patients. They had observed a surprisingly rapid healing which set in at once and afforded excellent results. Howorth was still optimistic in 1948, but now felt that the operation was most favourable during the stage of fragmentation or of healing. Steele (1943) used a considerably more radical method, removing the necrotic bone in the epiphysis by drilling through the neck and inserting fresh spongiosa instead. Thereby he obtained accelerated healing, but gave no further details concerning the shape of the head or the end result. The same operative procedure was used by Cathro & Kirkaldy-Willis (1963) who stated that they had observed several cases in which the epiphyseal plate regenerated after the operation. Camargo (1957) advocated a method of drilling a long plug of bone from the neck, but only just up to the epiphyseal cartilage which was not injured. The plug was then inserted upside down. After this procedure he observed quicker healing, which he explained as a possibly improved vascularization in the area. However, the method had afforded good results only when performed during the initial stage. Such plugging with bone seems to have been used in Germany where Neurath (1968) found a number of cases with total epiphysiodesis and poor shape of the head. Hirthe (1965) would not recommend the insertion of a bone plug after drilling, whereas Löwe (1969) preferred inserting a wedge of bone instead of nailing with a metal nail, after having tried both.

Svobodova & Svoboda (1967) compared the results in 105 patients treated by drilling with 700 treated conservatively. They would not recommend drilling despite a good effect in one-third. Chapchal (1965) too, in his textbook, opposed drilling, nailing, and bone plugging. He had used all methods, but had not observed better results or quicker healing than in conservative treatment. On the other hand, the operations involved a considerable risk of injuries resulting in poorer function of the joint. Instead, he recommended derotation osteotomy on the femur.

In the course of time it has been noticed that some femoral heads flatten laterally during the period of fragmentation and remain lopsided. In consequence, Garceau (1964) operated upon 21 such hips, chiselling off the lateral prominent part of the epiphysis, so that the remainder of the head could again fit into the acetabulum. He followed 7 of the operated patients, 3 of whom developed myositis ossificans. Regerettably, he did not mention how he avoided injuring the arteries supplying the epiphysis. The method does not seem recommendable.

Craig et al. (1963) were among the first to use derotation osteotomy on the femur or pelvic osteotomies, as they found LCPD to occur always in hips with appreciable anteversion, an average of 45^{o}, and believed that the aetiology was pressure necrosis on the anterior part of the head. The intention was to give the head a better position in the acetabulum. At the same time, they observed a considerably shortened healing period. Rinaldi (1964) also used correcting osteotomies, subtrochanteric or intertrochanteric, in 5 patients who were healing in an unfavourable varus deformity. He obtained a rapid healing. On the same motivation, Axer (1965) operated upon 12 patients. In an objective evaluation of the result he found the best results in patients who had early operation and among the youngest patients. This is of course not surprising.

Pipino & Simone (1967) also performed correcting osteotomies when this seemed needed, but also did partial osteotomy without correction in mild cases. Within both categories they observed a marked acceleration of the healing rate. In their opinion, this was due to changes in the local blood flow, transosseous phlebography demonstrating an altered direction of the venous discharge.

Osteotomy seems to be gaining ground as a therapeutic method, as it is being realized that it tends to accelerate healing. This has been observed also by Farkas (1969), Girod (1969), and Taussig & Hêripret (1969). However, it still remains an open question how the operation exerts a favourable effect upon the rate of the disease process, if it does, and whether it can possibly afford better healing results. The tendency is towards believing that it is the osseous hyperaemia resulting from the osteotomy which is disseminated all the way into the epiphysis where it increases osteogenesis. However, Haluzicky (1965) claims to have seen an increased rate of healing and absence of the fragmentation stage in 15 patients treated by the muscle detachment operation of Voss. Such a procedure would not be expected to cause hyperaemia of the bone for more than at most a couple of days. According to Sommerville (1971) it had not yet been established that healing could be accelerated by osteotomy, but he nevertheless used correction osteotomy to obtain a better position of the head in the acetabulum. The same therapeutic principle was used by Jani (1971), Haraldsson (1973) and Laurent (1973). Jani stated that the operation shortened the leg by a maximum of 1.5 cm. Hördegen & Witt (1971), after varisation osteotomy in 50 cases, discussed the approach on the basis of 20 of these patients. At all events they were adherents of a better containment within the acetabulum and the modelling effect of the varisation, but they obtained good results only when the operation was performed during the initial stage. Postoperatively, after healing of the osteotomy, they used short-lasting non-weightbearing in a Thomas caliper or allowed full weightbearing at once. Salter (1966) has performed corrections of the joint by pelvic osteotomy.

Operative treatment by osteotomy, usually with varisation or derotation, has gained ground in many countries during the past 10 years. Still, too little is known about the detailed results, both with respect to the rate of healing and the appearance of the head after healing. Axer & Schiller (1973) have reported the results in their 34 patients, but still there has not been any analysis of a sufficiently large operated material assessed with due regard to the various factors which influence the result, apart from the treatment.

Personally I doubt whether sufficiently good results are obtainable by operation without non-weightbearing at all ages, and in my opinion it is still of interest to know the value of the various treatments by non-weightbearing.

CHAPTER 6

LONG-TERM PROGNOSIS OF LCPD

Before the disease was described as a separate entity in 1910, Maydl (1897) and v. Brunn (1903), among others, had described osteoarthritis of the hip in older children. In his first paper from 1910 Perthes referred to these authors, and indeed he too looked upon the disease as juvenile osteoarthritis. However, there is nothing to indicate that the cases of osteoarthritis described before his time were due to LCPD.

Even though the X-ray film showed deformity of the joint with certain characteristics reminiscent of osteoarthritis, often as early as the time of primary healing in untreated cases, it was soon realized that the clinical appearances were not like those in true osteoarthritis.

Waldenström (1923) had followed 40 patients during the period after 1907. Out of 45 untreated hips only 4 had returned to normal. He observed that function was surprisingly good, even in the oldest patients, despite deformity of the hip.

Legg (1927), following 40 patients for more than 10 years, found that neither the cases showing the most favourable healing in mushroom shape nor the poorest ones with cap shape were incapacitated.

As the end result in 20 cases followed for periods of from 3 to 28 years, mean 8.5 years, Slocum (1941) found osteoarthritis in an astoundingly small number of cases. Among the patients with oval femoral heads none had osteoarthritis.

Sundt (1949), in the follow-up on 137 patients with 153 LCPD hips 10 - 52 years after the onset of the disease, observed radiological signs of osteoarthritis in 65 hips. Among the 11 spherical heads none showed osteoarthritis, but this increased in frequency with increasing deformity, being present in 16 of 56 oval, in 41 of 78 cylindrical, in and all 8 of angular shape. Only 17 patients had a reduced working capacity; 9 of them had severe complaints, disabling in 4.

Mindell & Shermann (1951) followed 72 patients with 78 hips for 1 - 40 years. They concluded that despite severe radiological changes there might be only mild or no symptoms in young adults, but that the symptoms increased with advancing age.

After more than 25 years' follow-up Helbo (1953) found osteoarthritis in 60% of 52 patients who had received only symtomatic treatment or none. These cases occurred in the deformed hips, none in those attaining spherical shape.

Ratliff (1956) reported the late results for 50 hips 11 - 30 years after the onset, mean follow-up period 17 years. Only 5 hips exhibited major osteoarthritis with pain although the X-ray films showed a good result, with a normal or slightly flattened head, in only 20 of the cases. Thirteen years later (Ratliff 1967) 34 of the patients were seen again, when the follow-up period averaged 30 years, range 25 - 40 years. 80% of the patients were free of pain and fully active, although only 14 hips were radiologically satisfactory. Only a few showed clinical or radiological exacerbation during the intervening 13 years. Two had been in hospital, one to undergo hip fusion. On the basis of this material the author concluded that a good result during childhood had largely kept the patients free of pain and in a good functional state, at least up to the age of 40.

Evans (1958) reported the findings in 52 patients seen 10 - 36 years, mean 16 years, after the onset. He found osteoarthritis only in the 16 with angular, irregular heads, not in 15 spherical and 21 elliptic with smooth surface.

Wansbrough et al. (1959), studying 129 patients followed for 5 - 26 years, admitted that as a rule the patients did very well, despite considerable deformity of the head, until they reached middle age. Only 5 were occupationally handicapped, and hip fusion had been needed in only 1 case.

Trueta (1960) briefly stated that a follow-up on 125 LCPD patients at an adult age to detect osteoarthritis showed this to be present only in deformed and incongruent joints. In a study on the aetiopathology of osteoarthritis of the hip Trueta (1963) found that its onset presupposes primary degeneration of cartilage, e.g. due to insufficient subchondral blood supply. This may be seen in incongruent hip joints. Trueta wrote: "There is no reason to believe that developmental joint diseases such as the osteochondritis of the Legg-Perthes type affects the joint in later days other than by the joint incongruency it may cause with its repercussion on the nutrition of the joint cartilage". The same opinion was expressed by Axhausen as early as 1923, who found that osteoarthritis might arise in two ways: The chondral type in which the cartilage is primarily degenerated, which it is not in LCPD, and the osseous type in which epiphyseal necrosis gives rise to irregular healing of the head and thereby an incongruous joint end which may wear the opposing cartilage, and osteoarthritis is the result.

Danielsson & Hernborg (1965) saw 35 patients more than 20 years, average 33 years, after the onset. They point out that the series is too small to justify final conclusions, but osteoarthritis was more severe and more common in patients with a high degree of deformity. Among their 14 patients with no or little deformity of the head none had pain, limitation of function, or major radiological changes, and all had normal mobility. On the other hand, they found all their 7 patients with pain, all 4 with restricted funtion, 12 of 15 with limitation of motion, and 9 of 11 with major radiological osteoarthritic changes among the 13 patients with the most severe deformity of the hip.

Eaton (1967) followed 100 LCPD hips in 88 consecutive patients, mean follow-up period 19 years, range 10 - 43 years. The 61 hips with a radius variation of less than 3 mm, measured by a template according to the principle of Goff, had satisfactory function, although only 7 of the heads were entirely spherical. 7 of the 88 patients wanted operative treatment because of severe complaints; 6 of these patients had strenuous physical outdoor occupations.

Sanders & Mac Ewen (1969) followed 40 of the patients from their material for more than 10 years. All who healed with a radius variation of less than 2 mm were still doing well, without complaints, and only a few of those with poorer healing had complaints.

An average of 36.3 years after the onset of the disease, Gower & Johnston (1971) studied 36 patients clinically and radiologically. The mean age was then 44.6 years. Most of these patients had been treated in a plaster cast. The most typical clinical findings were slight shortening and a slight limp, but little pain and negligible limitation of function. The symptoms did not increase with age or length of follow-up period. All 6 heads assessed as being spherical had good mobility and a normal width of the joint space, whereas all 9 patients with moderate or severe osteoarthritis had flattened heads. In a study of 475 arthroplasties for osteoarthritis of the hip only 4 exhibited the sequelae of LCPD. It is maintained also by Strange (1965) that among patients with osteoarthritis of the hip only a very few show X-ray appearances reminiscent of previous LCPD.

According to these reports on the long-term follow-up of patients with a history of LCBD, it seems justified to assume that femoral heads which are spherical and have a radius variation within the range of 2 mm encountered in normal series, run no risk of developing osteoarthritis, at least for 30 - 40 years and presumably onwards. It is indeed surprising that no complaints or instances of osteoarthritis have been reported in cases healing with a spherical caput magnum which according to Ferguson & Howorth (1935) involves a potential risk of osteoarthritis because of the altered weight-bearing conditions.

Similarly, the prognosis seems to be amazingly good in cases where the surface of the head is smooth and congruent with the acetabulum, although the radius variation exceeds 2 mm. These ovoid shapes make for moderate limitation of motion, but rarely pain, and apparently such patients remain capable of heavy unskilled labour, walking as well as standing. Whether the result will be maintained beyond a follow-up period of 30 - 40 years remains to be seen.

In cases where the head has healed in an irregular, angular shape, and is thus incongruent with the acetabulum, there is little doubt that the prognosis is poor, although Francillion (1967) reckons them only as possibly pre-osteoarthritic. Among such patients we find the few who have already been treated by operation or who want such treatment for their secondary hip complaints. All patients with functional or occupational problems and troublesome pain belong to this type.

CHAPTER 7

PRESENT MATERIAL

DEFINITION AND DESCRIPTION OF THE 4 SERIES:

The present study is retrospective and comprises a total of 475 patients in whom LCPD had been diagnosed and who had been treated by various forms of non-weightbearing under the supervision of hospital units.

Table 1.

TOTAL MATERIAL

		Method of treatment			
		Wheel-chair	Bed rest	Traction in bed	Thomas caliper
Total patients	475	141	96	156	82
Unilateral	388	114	79	113	82
Bilateral	58	21	13	24	0
Excluded	29	6	4	19	0

THE WHEELCHAIR SERIES consists of 141 consecutive patients started on the treatment at the Orthopaedic Hospital, Århus, during the 8-year period 1.1.1957 to 31.12.1964. The treatment was quite predominantly ambulatory, the patients being treated by non-weightbearing, sitting in a wheelchair. This series is the primary one, as the results of this therapeutic method have not previously been analysed.

For the sake of comparison, and in order to gather a sufficiently large number of patients for an overall assessment of LCPD, another 3 series were included in the material.

THE BED REST **SERIES consists of the 96 consecutive cases** started on treatment at the Seaside Hospital, Refsnæs, during the 5-year period 1.1.1953 to 31.12.1957. This series is identical with part of Mose's material (1964) and has already been included in another study (Meyer 1966). These patients were treated predominantly by long-lasting bed rest in hospital, followed by an ambulatory period with Snyder's sling and crutches, in some cases on an out-patient basis.

THE TRACTION IN BED SERIES consists of 156 cases, also consecutive, started on treatment at the Seaside Hospital, Refsnæs, during the subsequent 6-year period 1.1.1958 to 31.12.1963. The former half of this series is included in Meyer's study from 1966. In the great majority of these cases the strict bed rest was supplemented by intermittent, light traction. As a rule the traction periods lasted for 6 weeks, with 1 - 1½ kg traction on each leg by rubber foam fixation and the hip joints in slight flexion and abduction, alternating with a 2-week bed rest without traction. After 6 or 7 periods of traction the patients were kept in bed for 4 - 6 months. Thereafter, they were ambulatory with Snyder's sling, as in the above series, but most often they were kept in hospital throughout.

THE THOMAS CALIPER SERIES consists of 82 patients, treated predominantly by ambulatory non-weightbearing in a Thomas caliper. The first 59 patients were treated in the Orthopaedic Hospital, Århus, during the period 1949 - 1955 and the last 23 at the Orthopaedic Clinic, Odense, during the period 1952 - 1963, before both units changed to wheelchair therapy. During these two periods the therapeutic, and especially the follow-up principles were not adhered to quite as systematically as later. To avoid operating with a large consecutive material, and having to exclude many cases, I selected this series. The criterion for selection was that X-ray films were still available for the entire duration of the disease, as this made it possible to compare the course and result with those in the other series.

From the first 3 series 29 patients were excluded and are not considered in any part of the analysis. The motivation for these exclusions is apparent from the patient lists. From the wheelchair series 6 patients were excluded (Cases 25, 73, 77, 105, 121, and 140). Two had a history of congenital dislocation of the hip, one developed epiphysiolysis of the femoral head later, one has developed rheumatoid arthritis with severe changes in the hip joints, one died of congenital heart disease, and one received no treatment at all, as the disease was not detected until at an advanced stage, when she was 13 years of age. From the two Refsnæs series I excluded 4 and 19 patients respectively. These exclusions were performed in accordance with the two previous investigators, to render the results of the present analysis comparable with theirs.

Among the remaining 446 patients the main emphasis was laid on analysing the 388 patients who had unilateral LCPD. In all four series these cases were recorded as regards sex, side affected, age at institution of treatment, duration of symptoms, nature and duration of treatment. The entire radiological course was analysed. Particular attention was given to the subjective as well as objective staging at the institution of treatment. Moreover, the result after healing was assessed objectively by studying the shape of the femoral head and its inner structure in both views and comparing the findings with the healthy femoral head.

In addition, the wheelchair series was subjected to further analyses of various kinds which will be reported below.

In 58 patients the disease was bilateral. Regardless of whether both sides were affected at the same time or at an interval, and regardless of the severity of the current radiological changes, they are considered bilateral. These cases were not analysed quite as thoroughly, especially not with respect to an accurate grading of the X-ray appearances. They will be discussed in Chapter 12.

NON-WEIGHTBEARING TREATMENT IN A WHEELCHAIR

In 1955 Professor E. Thomasen of the Orthopaedic Hospital, Århus, conceived the idea that patients with bilateral LCPD could be protected from weightbearing by out-patient treatment in a wheelchair. The method was described in 1969 (Thomasen). This idea was based on the wish for non-weightbearing with the hip in a flexed position in order thereby to reduce the compressive action of the muscle traction upon the femoral head and at the same time place it well into the acetabulum (cf. Fig. 5, p. 9). The method soon proved so suitable that the Thomas caliper treatment of unilateral cases was abandoned. From 1957 all patients referred to the hospital with LCPD have been treated in a wheelchair. During the period up to 1964, which is comprised by the present analysis, the Physical Therapy Hospital at Hald was an administrative unit under the Orthopaedic Hospital in Århus with orthopaedic consultants from there. Thus patients transferred from other units to Hald are also included in the present material. Of the 141 patients 27 had been in-patients at Hald. This includes 11 bilateral cases. Five of the 16 unilateral cases had been admitted only temporarily for a short time to relieve the family of the therapeutic responsibility, and for the same reason 2 patients were temporarily admitted to another hospital unit. 7 patients had been treated temporarily by a Thomas caliper in another orthopaedic unit before being transferred to Hald and switched over to wheelchair treatment. Of these 7 patients 4 had started as unilateral cases, but had developed LCPD also on the other side while being treated with the Thomas caliper. Apart from the 7 treated with Thomas caliper, another 5 had received other treatment before wheelchair therapy was started. These 5 patients had been treated by bed rest elsewhere for more than one month, 4 of them for bilateral LCPD. Three of them were transferred to Hald.

At the institution of wheelchair therapy all the patients are provided with a specially made brace of felt-padded girth. The brace keeps the hip joints flexed and also completely prevents extension in the knee joints (Fig. 10). As long as the child is wearing the brace it cannot get up from the chair without the utmost difficulty, and at least is unable to get up and walk with extended legs. In other words, by means of this brace the child may be left to itself while playing with chums and need not necessarily be under adult supervision all day long. The brace is not worn during the night.

During the period from which the present series is derived we used a chair of Danish make, with stiff back and stiff seat.

Fig. 10: Wheelchair patient wearing the hip flexion brace.

Since then, the chair has been altered, so that now it is collapsible, but the stiff seat has been preserved. The large wheels have always been placed well forward, to make it easier for the children to overcome minor hurdles on the ground.

25 unilateral and 6 bilateral cases spent less than 1 month at the Orthopaedic Hospital, Århus, while the brace was made and the chair prepared. In most cases the stay in hospital was only about a week, so that the child could just get used to the method. 8 unilateral and 6 bilateral cases were in hospital elsewhere for less than one month before being transferred to Hald, where the wheelchair treatment was initiated. The remaining patients were protected from weightbearing in bed at home for approx. one week until the brace had been made.

All the patients were followed clinically and radiologically about every 3 or 4 months. The non-weightbearing treatment was finished when the femoral head had advanced so far in the period of repair that it was deemed capable of bearing weight. In this respect emphasis was attached to increasing regeneration of bone in the translucent areas of the epiphysis and reconstruction of the surface contour.

Fifteen patients were protected from weightbearing by a Thomas caliper after their time in the wheelchair. Eight of them belong to the first year of the study (1957). The others were transferred, for a variety of reasons, to another orthopaedic unit where the Thomas caliper was preferred. Thus, 2 were after-treated in a Thomas caliper for less than 6 months, 2 for 7 - 12 months, and 11 for more than 12 months. 12 of these cases were unilateral, and all are included in the analysis of the results. Thus, the wheelchair series comprises a group of patients treated somewhat differently, but in the great majority of cases by non-weightbearing sitting in a wheelchair, and this treatment was performed at home, if at all possible.

The non-weightbearing period for the 135 patients of the wheelchair series is shown in Table 2. The mean non-weightbearing period was 22.8 months. It is calculated as having started from the patients started the treatment by bed rest, Thomas caliper, or wheelchair until the treatment with wheelchair or Thomas caliper was discontinued and they were allowed to bear weight on the affected leg.

Table 2.

TREATMENT PERIOD IN
WHEELCHAIR SERIES

Months		≤12	13-18	19-24	25-30	31-36	>36
Unilateral	114	7	16	36	31	14	10
Bilateral	21	2	3	8	3	3	2
Total	135	9	19	44	34	17	12

PRACTICAL PERFORMANCE OF THE WHEELCHAIR TREATMENT:

The main reasons for keeping LCPD patients in hospital during non-weightbearing treatment are:

(1) that a method of treatment is wanted in which the patients are to be so restricted in their mobility that the presence of a nursing staff is needed, or

(2) that supervision by the hospital staff is to secure that the selected method of treatment is being observed.

Strict bed rest for the long period required in LCPD is hardly practicable on an out-patient basis except under very special, favourable environmental conditions. It must even be presumed that it is difficult to carry through completely during a stay in hospital, as the nursing staff is not in the wards around the clock. According to Pedersen & McCarrol (1951) the main value of traction is possibly that it is the best safeguard against the patients getting out of bed.

Observance of the Treatment

In all ambulatory methods of treatment, the observance of the treatment escapes continuous medical control. Out-patient follow-up at intervals of months affords no guarantee that the treatment is being observed. One cannot expect honest answers from the parents to questions as to how they manage observing the treatment and safeguard against the children cheating. Parents who are not up the job are apt to conceal this, fearing that the child will then be taken to a hospital, perhaps far from their home, or that they will be reproached for lacking care.

It was important, therefore, to investigate how the wheelchair regime was in fact being administered under the widely different social and housing conditions. Now, 5 - 10 years after the treatment period, I visited the homes and interviewed the parents concerning the problems relating to the treatment. The interviews were according to a standardized questionnaire, aiming in form and content at the greatest possible objectivity. It was pointed out to the parents that the result of the interview study depended entirely upon the honesty of the answers, and indeed I received an impression of good contact and honest answers in practically all cases. Some families had moved since the treatment period, but the majority were visited in the same environment in which the treatment had been carried out; this afforded ample possibilities of understanding the individual problems. Out of the 114 patients with unilateral LCPD, 11 who had spent the entire treatment period at Hald and one patient who was in an orphanage were excluded from the interview study. In the subsequent analysis of the results these 12 patients were classified among those perfectly protected from weightbearing in the wheelchair. Out of the remaining 102 families 100 were visited, whereas two could not be traced. The 11 patients with bilateral LCPD, who had spent the entire treatment period at Hald, were also not visited. Of the remaining 10 bilateral cases 9 were interviewed.

Result of Interview Study:

On the basis of the parents' replies the performance of the treatment could easily be classified into the following 3 groups:

Perfectly protected from weightbearing
Well " " "
Badly " " "

Perfectly protected from weightbearing: In these cases the parents had been capable of observing the given instructions. The children had allegedly spent practically their entire time in the wheelchair, from morning till night, out of doors as well as indoors. They were carried up and down stairs, carried to and from the toilet and bath, carried to other furniture, carried in and out of the car. This group comprises 21 of the 100 unilateral cases.

Well protected from weightbearing: This applies to 60 of the 100 unilateral cases. The non-weightbearing in these cases had been somewhat less rigorous. It was characteristic of these cases that indoors the children had done without the wheelchair. However, they had been kept sitting almost all the time. They had often sat on the floor while playing and had propelled themselves from place to place on their buttocks by their hands and feet. Some of them had managed the stairs in the same, sitting position. The great majority of these patients had periodically, or when doing certain things, borne weight on the good leg, and one-third had often jumped around on it. About half the parents of this group admitted that for short periods, or on a few occasions the children had been caught bearing weight on the involved leg.

Badly protected from weightbearing: To this group the author assigned 19 of the 100 unilateral cases, whose parents candidly admitted that they had been unable to keep the child from weightbearing. Throughout the treatment period all these children had often borne weight on both legs, to a varying extent. However, 16 had mainly borne weight on the good leg, trying to spare the affected leg somewhat. In 8 cases it was claimed that the brace had been used consistently, but that nervertheless the child had borne weight on the flexed hip joint. A few had managed running around with the wheelchair on their backs, as they had been chained to the chair with extra reins, often padlocked. A very few parents stated that they had completely given up keeping the child in the chair and had put it aside. However, the majority had fought a constant struggle with the children in the attempt to keep them sitting in the chair, or at least preventing them from bearing weight, but allegedly the children had been unmanageable.

The 9 bilateral cases included in the interview study are distributed by 2 perfectly, 5 well, and 2 badly protected from weightbearing. This is exactly the same distribution as for the unilateral cases.

Apart from this, the study showed that the parents had to a marked extent been able to solve efficiently the numerous minor everyday practical problems. Most children over 6 years had been able to dress and undress. The boys had usually urinated into a flask while sitting in the chair. 12 of the unilateral cases had been at nursery school part of the treatment period, which had considerably relieved their mothers. Only one nursery school had failed to understand that special regard had to be paid to the patient. 63 of the 100 unilateral and 5 of the bilateral patients had attended school during part of the treatment period, and in 54 of these cases the schools had shown a full understanding of the therapeutic principle. In several cases the patient's classroom had been placed with due regard to stairs. Often the patients had been able to propel their chairs to school and back home, if the distance was not too long, or else they were wheeled by their mother, siblings, or classmates. If the school was far off, the transport had been by ambulance or taxi, and some of these patients had had one wheelchair at home and an extra one at school. In 3 instances the school authorities had selected home teaching by one of the teachers for an hour or two daily. In these cases, however, the children found it difficult to keep up with their classmates when they could start school after the treatment had been completed.

CONCLUSION: In one-fifth of the cases it had proved possible to keep children with LCPD perfectly protected from weightbearing in their homes for about 2 years in a wheelchair, whereas in another one-fifth this had been quite impossible. In three-fifths of the cases the non-weightbearing could be accomplished fairly well, if the children were allowed to get out of the wheelchair in situations where they wanted to sit or move about freely in a way other than by ordinary walking or running. The non-weightbearing method with wheelchair is compatible with the child playing with chums of his own age and taking part in school instruction in the normal way, if only the environment has the understanding that special regard has to be paid to these patients.

Role of Social Conditions.

An attempt was made to ascertain:

(1) Whether the possibility of protecting children from weightbearing in a wheelchair depended upon the social or housing environment.

(2) Whether the problem of transporting the child and chair up and down stairs and cleaning problems when the wheelchair was to be used both indoors and out of doors bore any relation to the observance of the treatment.

(3) Whether the parents had missed further aids, e.g. an extra wheelchair or public financial support, or whether perhaps they would rather have been exempt from the responsibility for the treatment, preferring to have the children in hospital or some

other therapeutic institution.

(4) Whether the degree of non-weightbearing had any influence upon how long it took the child to walk normally anew, when the treatment had been finished.

The results are shown in Tables 3, 4, and 5. It will be seen that the distribution of the bilateral cases is entirely identical with that of the unilateral ones.

Table 3. Non-weightbearing in a wheelchair in relation to social conditions:

Protected from weightbearing:		Unilateral cases: Perfectly	Well	Badly	Bilateral cases:
Patients	100	21	60	19	9
Geographic:					
Urban	63	13	39	11	6
Rural	37	8	21	8	3
Housing:					
House	51	13	30	8	5
Flat	33	5	20	8	3
Farm	16	3	10	3	1
No. of children in the home:					
≤ 2	40	7	23	10	4
> 2	60	14	37	9	5
Social group:					
Unskilled labourer	29	6	19	4	4
Skilled labourer	24	5	14	5	3
Trade and agriculture	23	5	12	6	1
Salaried worker	13	1	9	3	0
Liberal	11	4	6	1	1
Mother working	16	1	10	5	1

Re (1) (Table 3).

It may be seen that the 3 groups of observing non-weightbearing were entirely independent of whether the children lived in a town or in the country, in a house, in a flat in a tenement house, or on a farm. It was also independent of the educational social group to which the parents belonged and of how many other children they had to look after. The slight preponderance of perfectly observed non-weightbearing in the group of liberal occupation and of badly observed non-weightbearing in children whose mother was working, and children who lived in flats can be regarded merely as a tendency. The numbers involved are too small for statistical calculation.

Table 4. Non-weightbearing in wheelchair in relation to problems connected with the treatment.

Protected from weightbearing:		Unilateral Perfectly	Unilateral Well	Unilateral Badly	Bilateral
Patients	100	21	60	19	9
Cleaning problems	51	11	30	10	6
Stair problems	41	8	23	10	6
Wish for 2 wheelchairs	58	13	33	12	6
Wish: Collapsible chair	43	9	28	6	5
Brace used consistently	50	10	32	8	5
Extra fixation needed	28	5	16	7	1
Financial strain	25	5	14	6	3
Wish: Treatm. in hospital	11	0	3	8	0

Re (2) and (3) (Table 4).

Managing stairs and cleaning problems also had no influence upon the treatment. A little more than half the families would have liked having 2 chairs, and the majority would prefer one of them to be a light, collapsible model. This wish was prompted mainly by stair- and transport problems. The majority living in flats had great problems in managing the staircase, and only 2 out of 33 had accomplished carrying the chair up and down every day, often several times daily. Three had had an extra chair in the flat. The families living in houses and especially those living on farms had great cleaning problems, and for this reason they sorely wanted two chairs. The wish for a collapsible extra chair was due in large measure to the possibility of transporting it in the car. Many did not have a car during the treatment period, but with the increasing use of motor cars during the past 10 years, this wish must now be considered almost universal. It was found that only half the children had used their brace consistently. However, this was of no importance to the quality of non-weightbearing. About one-quarter of the parents had used extra fixation of the child to the chair, mainly by fastening the brace to the chair to prevent the child from falling off while playing, but in a considerable proportion of the most badly protected cases by the above mentioned, more drastic method. 25% of the parents had felt the ambulatory non-weightbearing in a wheelchair to be a slight financial strain. The children had worn their sleeves heavily when operating the large wheels of the chair. On the whole, the extra expenses involved had been very small. The financial aspect bore no particular relationship to the social group, apart from that of working mothers. This group was the only one in which the financial aspect had been of real importance, either because the mother had given up working to be able to look after the sick child or because someone else had to be paid to do so. Even though it had been felt as an extra physical strain, increased work, and responsibility to have the child on ambulatory treatment, only 3 out of the 81 families who had managed the treatment would have preferred it to have been in an institution. On the other hand, this wish was stated by 8 out of the 19 families who had failed in the treatment.

Table 5. Treatment in wheelchair in relation to training period until normal walking:

Protected from weightbearing:		Unilateral			Bilateral
		Perfectly	Well	Badly	
Patients	99	21	60	18	9
None	35	0	19	16	2
Less than 1 month	36	8	28	0	3
1 - 3 months	28	13	13	2	4

Re (4) (Table 5).

There was a definite relationship between the degree of non-weightbearing and the time it had taken to train the child up to normal walking. The best protected children had usually taken a month or two to learn normal walking, whereas 16 of the 18 patients who had the poorest protection from weightbearing could walk normally the very day that the treatment was discontinued.

The 19th patient of the badly protected group is not included in this table, as he was admitted to hospital where he was treated with strict bed rest during the final part of the treatment period, because the non-weightbearing in the wheelchair could not be observed at home.

In CONCLUSION: The geography of the residence, housing, the parents' social and financial status, or the size of the family have no influence upon the way in which the ambulatory non-weightbearing treatment with wheelchair can be carried through. A constant use of the brace is not needed to keep the children protected from weightbearing by the wheelchair method. In most cases the family has more need of extra practical and social aid - e.g. an extra collapsible, light wheelchair and a nursery school for the child - than of direct financial aid. The latter should rather be reserved for single mothers and for families in which the mothers stop working in order to be able to supervise the treatment. In return, these last-mentioned cases need quite appreciable financial aid. The ability to carry through the long-lasting ambulatory non-weightbearing with wheelchair must be assumed to depend upon psychological, temperamental, and educational factors in the affected child and its parents. Only families who are unable to carry through the ambulatory treatment for such reasons want to leave the responsibility to a therapeutic institution.

FAMILIAL PREDISPOSITION:

Apparently no one has as yet made thorough studies of heredity in LCPD. However, Stephens & Kerby (1946), studying a family in 5 generations, found 28 to have suffered from LCPD or changes in the hip that might be its sequelae. Among four generations of another family Monty (1962) found 5 cases of osteoarthritis of the hip, possibly due to LCPD. Wansbrough et al., in 1956, reported a familial incidence of 1:35 in a study of 124 families and in 1959 a familial predisposition in 10% of a material comprising 129 patients. Edgren (1965) found 6.4%, whereas Taussig and Héripret (1969) found only 2.2% with familial predisposition. Giannestras (1954) and Bernbeck (1967) have each described a pair of monozygotic twins with LCPD in both, but at different times.

I had no intention of studying the heredity in any detail. However, while reviewing the wheelchair series, and especially in the interview study, I looked for known familial cases of LCPD or other diseases of the hip. In 16 instances there was a confirmed predisposition to LCPD in the family, in 8 there had been instances of congenital dislocation of the hip, and 30 could report other, not further specified hip disease among adult relatives.

The 16 examples of confirmed LCPD predisposition will be briefly mentioned:

Case 2: A son of his father's cousin had been treated for unilateral LCPD by a Thomas caliper. Another cousin of his father's had been treated for a hip disease during childhood; diagnosis uncertain.

Case 6: A son of his mother's sister had been treated in a wheelchair for unilateral LCPD. His father's brother had had a hip disease, of unknown type, during childhood.

Case 7: A 3 years elder brother had been treated for unilateral LCPD with a Thomas caliper for 4½ years.

Case 30: A 12 years younger brother treated for unilateral LCPD by a Thomas caliper at the age of 6 years.

Case 51: A son of his father's sister had been treated for unilateral LCPD in a wheelchair at the age of 5 years.

Case 52: The brother of Case 118.

Case 53: A son of his mother's brother is Case 54, and a sister of his maternal grandmother has congenital dislocation of the hip.

Case 54: The cousin of Case 53.

Case 55: The brother of Case 96.

Case 59: Father treated for LCPD by traction and bed rest at the age of 8 years.

Case 72: Two younger brothers treated for unilateral LCPD in wheelchair, started in 1966 and 1968 respectively. Mother and one of her brothers had shortening of one leg and slight hip trouble, but had not been examined.

Case 78: A sister of her mother's treated for unilateral LCPD with crutches during childhood.

Case 92: A younger brother treated with bed rest and since 1955 in a wheelchair. His mother had a history of untreated LCPD at 3 years. At the age of 25 she had an operation inserting a hip prosthesis by the Judêt method, and since then the hip had been ankylotic.

Case 96: The brother of Case 55.

Case 118: The brother of Case 52.

Case 129: Mother's cousin treated for unilateral LCPD with a Thomas caliper.

Out of the 135 patients in the wheelchair series 6 were related to one of the others. Thereby, the familial incidence is 13 cases in 132 different families.

This study of the familial incidence is far from complete, and accordingly it is not possible to calculate any accurate percentage for the familial incidence. However, it seems fairly certain that 13 known cases of LCPD among 132 families and 8 cases of congenital dislocation of the hip in the same families is far more than would be expected of these fairly uncommon diseases. I, therefore, feel justified in drawing the following

CONCLUSION: The investigation of the wheelchair series confirms that there is a genetic factor in the development of LCPD and a genetic relationship between LCPD and congenital dislocation of the hip.

SYMPTOMS AND CLINICAL SIGNS:

Clinical symptoms

Among the 114 unilateral cases of the wheelchair series the predominant symptom was a limp, in a number of cases combined with pain in the hip or knee. The symptoms are listed in Table 6:

Table 6. Predominant symptom.

	No. of pts.	%
A limp only	68	59.6
A limp + hip pain	17	14.9
Hip pain only	15	13.3
A limp + knee pain	6	5.2
Knee pain only	6	5.2
A limp + hip and knee pain	2	1.8
	114	100.0

81.5% with a limp and 40.4% with pain corresponds very closely to Cameron & Izatt's statement from 1960 about 183 patients among whom these findings were made in 78% and 41% respectively, whereas Wilk (1965) found a limp in 95% of 186 patients and Slocum (1941) pain in 69% of 86 patients.

A limp is the predominant symptom of LCPD, and it cannot be sufficiently emphasized that a child with a limp should always have his hip joints X-rayed in two views, even in the absence of pain.

Trauma

In 21 cases (18%) a trauma was stated to have initiated the symptoms. Broder (1953) found trauma in the history of 22% among 91 patients. There are, however, marked variations in the reports on trauma. For instance, Taussig & Hêripret (1969) found only 4.7% and Kemp & Boldero (1966) 30% in series of more than 250 patients.

Duration of Symptoms Before Diagnosis

The length of time that the patients had had symptoms before they were X-rayed and the diagnosis was made is apparent from Table

Table 7. Duration of symptoms

≤ 1 month	38 (33%)
1 - 3 months	40 (35%)
4 - 6 months	27 (24%)
7 - 12 months	6 (5%)
> 12 months	3 (3%)
Total	114 (100%)

Thus, 68% had had symptoms for 3 months or less and only 3% for more than 1 year.

At the interview study of the 100 patients the parents were asked whether the hips had been X-rayed immediately after they had first consulted a doctor. In 29% of the cases this had not been done, the symptoms being interpreted as "growing pains" (Øster 1972). Thereby, the diagnosis had no doubt been delayed, as 59% (17 of these 29%) had a duration of symptoms exceeding 3 months as compared with 32% of the entire series. Moreover, 59% had flattening of the epiphysis at the first X-ray examination as against an average of 41% for the entire series.

Out of the 21 patients who had a history of trauma only 12 had complained of pain, and the disease was diagnosed in only 8 of them before the symptoms had lasted for one month. This does not indicate that the traumas have given rise to immediate symptoms. 16 patients had had symptoms for less than 3 months, and in 16 cases the disease was diagnosed at an early radiological stage, before flattening of the epiphysis had occurred. However, this is not any major difference from the findings in the series as a whole. In other words, it is not possible to demonstrate a definite relationship between trauma and LCPD in the present study.

Clinical Signs.

At the first examination in the Orthopaedic Hospital, Århus more emphasis was laid on the assessment of the X-ray films than upon a thorough physical examination of the patient in all cases where the diagnosis was evident. Therefore, the case notes do not systematically include information about the type of the limp, the presence of Trendelenburg's phenomenon, or recording of the site and degree of muscular atrophy.

The range of motion in the hip was studied in 102 of the 114 unilateral cases. In 7 there was no limitation of motion in the affected joint. In the 95 patients with restriction of motion, this applied almost equally often to abduction: 82 cases, internal rotation: 76 cases, and external rotation: 79 cases. Restricted adduction was found in less than half the cases (45%) and restricted flexion in less than 1/4 (22%), but among the latter there was some preponderance of patients in a late radiological stage.

CHAPTER 8

METHODS OF MEASUREMENT

ASSESSMENT OF PREVIOUS METHODS:

When analysing the results in a group of LCPD patients having a follow-up period of less than 10 years most emphasis has to be attached to a purely radiological evaluation.

As early as 1924 it was demonstrated by Møller that without treatment the clinical results were good in 78.4%. In a study of 102 patients Levy & Girard (1942) found that a good clinical result often co-existed with a poor radiological result. In a mixed clinical-radiological classification into 4 groups they therefore based their grading mainly upon the X-ray appearances. A similar mixed clinical-radiological assessment was used by Mindell & Shermann (1951), Wilk (1965), and Jacchia & Faldini (1967). The few clinically poor cases always show a poor radiological result (Löwe 1969, Steinhauser 1970).

However, the methods used by the above-mentioned authors are not sufficiently objective. The patients state no or very few complaints, and even a physical examination for limp, atrophy, and restriction of motion in the hip joint is often interpreted as normal or good, although it may be classified as rather poorer than what the patient feels (Herndon & Heyman 1952). Radiological assessment in these studies has been based mainly on an estimate of shape and the degree of deformity, if any. Accordingly, these methods are inapplicable for comparing the results of different authors.

To be able to grade the results more accurately and objectively most authors have applied measuring methods to the X-ray films. Eyre-Brook (1936) introduced the epiphyseal index as $\frac{\text{height of epiphysis}}{\text{breadth of epiphysis}} \times 100$. Regrettably he did not specify, neither by word nor drawing, how he carried out the measurement. The epiphyseal index must differ widely according to how it is measured. The height may be measured so that one point is the middle of the epiphyseal surface or possibly the site where the distance to the epiphyseal line is longest. The other point may be selected anywhere in the zone of the epiphyseal line, which is often 2 - 3 mm wide. Thus, the height may range from e.g. 10 - 13 mm. Breadth may be measured either at the widest site of the epiphysis or at the junction to the epiphyseal line and may thus easily vary e.g. from 43 - 46 mm. In this example, then, the epiphyseal index will vary from $\frac{10}{46} \times 100 = 22$ to $\frac{13}{43} \times 100 = 30$ or 36% in relation to the former measurement. This perhaps explains why Helbo (1953), in his normal material of 150 hips, found higher index values than did Eyre-Brook. Both reported that normally the values vary with age, but with marked individual differences within each age group, as is confirmed by Table 8. The epiphyseal index method has been used in a number of analyses: Pedersen & McCarroll 1951, O'Garra 1959, Cameron & Izatt 1960, and Cathro & Kirkaldy-Willis 1963. It was pointed out by the last-mentioned authors that the epiphyseal index tells us nothing about the shape of the epiphysis or of the femoral head. Therefore the method is inexpedient for prognostic studies, inaccurate as a measure of the therapeutic result, and inapplicable for comparison with the results of others.

Sjövall (1942) introduced the epiphyseal quotient (EpQ), signifying the epiphyseal index of the involved side in % of the epiphyseal index of the good side. This method restricts the use to unilateral cases, but eliminates to a marked extent the individual differences in the normal index, provided that the measurement is made according to the same criteria on both sides. Stamp et al. (1959), applying this method to a comparison with clinical evaluation, found a fair parallelism, the predominant majority of the clinically satisfactory cases having an EpQ over 70% and the predominant majority of the clinically poor cases below 55%. Mose (1964) also laid the main emphasis on the epiphyseal quotient, which he related to the shape of the epiphysis assessed by a template. He reported that when the epiphysis was part of a sphere this was usually tantamount to an epiphyseal quotient exceeding 60. Katz (1957) also attached most importance to the evaluation of the EpQ. Helbo (1953) too used the EpQ combined with assessment of the shape, but called the quotient the "Caput Quotient". However, Helbo is far from being the only author to use the epiphysis as a synonym for the head. To do so is a serious error, as the epiphyseal surface normally constitutes only about two-thirds of the surface of the head, and its volume is only rather more than half that of the head. The epiphyses of involved heads are diminished and the head enlarged, so that the ratio will be considerably higher (cf. the calculations in Fig. 11, showing a very favourable healing result). The epiphyseal quotient represents only the proportions and flattening of the epiphyseal portion at healing, and affords no information about the state of the head as a whole. Furthermore, it tells us nothing about the shape and congruency of the joint surface. Therefore, assessment solely of the epiphyseal quotient is an inadequate basis for analysing results.

Heyman & Herndon (1950) introduced a "comprehensive quotient" (CQ), including the epiphyseal quotient as one of 4. The other quotients are: head-neck quotient, which relates the total shortening of the head-neck to the increase in width of the neck, acetabular quotient which assesses the depth of the acetabulum in relation to its width, and the acetabulum-head quotient which is a measure of lateral subluxation of the head in the acetabulum. This measuring method gave a more varied assessment of size and adaptation in the entire region of the joint. As the method was published with good drawings, with a fairly clear indication of the points of measurement and a quotient score grading the results into 4 groups: excellent, good, fair, and poor, it ought to be applicable for comparing the results of different authors. Indeed, it has been the most commonly used method in all parts of the world during the past 20 years (Herndon & Heyman 1952, Broder 1953 and 1958, Wansbrough et al. 1959, Ralston 1961, Reimann 1961, Chung & Moe 1965, Harrison & Menon 1966, Cumming 1967, Harrison et al. 1969, Taussig & Héripret 1969).

Even though Heyman & Herndon's CQ apparently was an extended and improved method of evaluation, several objections may be raised. In the first place, the CQ does not say whether the surface of the head is spherical; in the second place, the method is cumbersome, requiring 16 measurements on each film and a great job of calculation.

Mose (1964) used the transparent template with concentric circles described by Goff (1954) for assessing whether the head was spherical, and at the same time he calculated the CQ. Out of

141 heads with a CQ exceeding 80, corresponding to "good", he found that 23 were irregular when measured with the template. On the other hand, he found a good correlation between sphericity and an EpQ over 60, and accordingly he classified the spherical heads with an EpQ over 60 as "good". Edgren (1965) used another type of template to assess whether the head was spherical.

Realizing the inadequacy of these measuring methods, Meyer (1966) was the first to differentiate Mose's method. By means of the template he assessed whether or not the entire head was spherical. Thereafter, he graded the spherical heads having different quotients. The EpQ was calculated on the basis of the epiphyseal width at the junction to the epiphyseal line and the height measured down to the middle of the epiphyseal line. To obtain a measure of the structure of not only the epiphysis, but of the entire head he introduced another two quotients, the joint surface quotient (JsQ) and the radius quotient (RaQ). The JsQ calculated from the measurements of height and radius of the entire head in both hips, signifies how large a percentage the healed head constitutes of the entire surface of a sphere as compared with the findings on the uninvolved side. The RaQ is a measure of the degree of caput magnum and thereby to some extent a measure of how far the head projects laterally to the acetabular margin. Both quotients are better prognostic measures than the EpQ.

The analysis of the present material was carried out on the basis of Meyer's classification and quotients. Like other quotient methods, this one is applicable only in unilateral cases.

PRESENT MATERIAL:

As early as 1921 Waldenström stated that the shape of the femoral head does not alter after the primary healing. The films on which I based the assessment of the present material were selected according to the following principle: In reviewing the radiological course in each individual patient, the time of primary healing was recorded, i.e. the time at which structural changes in the epiphyses were negligible. By far the greater part of the patients were followed at 1-2-year intervals after that time. I selected the first set of films after primary healing in which the quality with respect to sharpness and symmetry was best, and where both hips had been X-rayed in the anteroposterior view as well as in Lauenstein's position. At the time of the assessment between 6 months and 2½ years had elapsed since primary healing in most patients of all 4 series, regardless of their chronological age.

The mean follow-up period from the institution of treatment up to the X-ray film which formed the basis of assessing the result differed somewhat in the 4 series.

Wheelchair series:	5.34 years
Bed rest series:	4.56 years
Traction in bed series:	4.10 years
Thomas caliper series:	6.10 years

The difference is due partly to the radiological follow-up having been more consistent and somewhat more frequent in the two in-patient series than in the two ambulatory series and partly to a slightly quicker healing time in the traction series.

CRITERIA FOR THE MEASURING METHODS:

Re Shapes.

The osseous contour of the entire cartilage-covered part of the femoral head was assessed by a transparent, firm template with concentric circular lines at 2 mm intervals according to the principle of Goff and Mose.

As spherical I assessed all heads whose contour in both planes followed a given circular line or fell within two neighbouring lines. In other words, spherical heads are those in which the radius variation is ± 1 mm, in the individual measurements as well as in the difference often present between the anteroposterior and the Lauenstein views.

All heads which did not fulfill this demand were classified as irregular, and when the radius varied by more than 4 mm the classification was very irregular.

A tolerance like that stated in assessing sphericity is in accordance with the findings of Schiller & Axer (1972) in their evaluation of capital shape in two planes using Edgren's template. The tolerance did not alter, although the films had been taken with the hip joints a bit asymmetrical. Measurements on the normal material in this investigation also showed a variation of ± 1 mm from sphericity, and studying normal adult femoral heads Hammond &

Charnley (1967) found a variation on the bone of 1 mm from sphericity in the frontal plane, whereas the variation on the cartilaginous surface was less marked.

Re Quotient Measurements.

Epiphyseal quotient measurement: Epiphyseal height A was measured on the highest point of the epiphysis perpendicular on the epiphyseal line. One point was placed at the junction to the epiphyseal line, the other one at the surface contour.

Epiphyseal width B was measured at the broadest site. These points were selected as they proved the most reliable ones to fix accurately. The same criteria were used in measurements in both planes and on both sides. The measurement accuracy was 1 mm. Whenever there was doubt about which mm line was applicable, the lower one was selected.

Joint surface quotient measurement was done according to Meyer. The height of the head was measured from a baseline drawn between the assessed cartilage border at right angles to the surface contour at the highest site. The end point of the baseline is easy to fix medially where the junction to the femoral neck is sharp and coincides with the cartilage border. Laterally the cartilage border was estimated to be situated about 2 mm distally to the epiphyseal line. Anteriorly and posteriorly the sharp junction to the neck was chosen, as these points are easy to fix, although the cartilage border is 1 - 2 mm more proximally. It was estimated that this distance to the cartilage border was the same on the involved and uninvolved head, so that difference in the measuring point would be eliminated in the calculation. Thus, it was endeavoured to place the baseline as objectively as possible. The radius of the head was measured by the aid of the template. In a few cases, in which there was doubt as to the placement of the surface contour in either of two neighbouring intervals, as in both it might fall within two adjacent lines the more central interval was selected, and the radius was read from the more peripheral of the lines. The accuracy of this measurement was also 1 mm.

Radius quotient measurement: Read directly from the above.

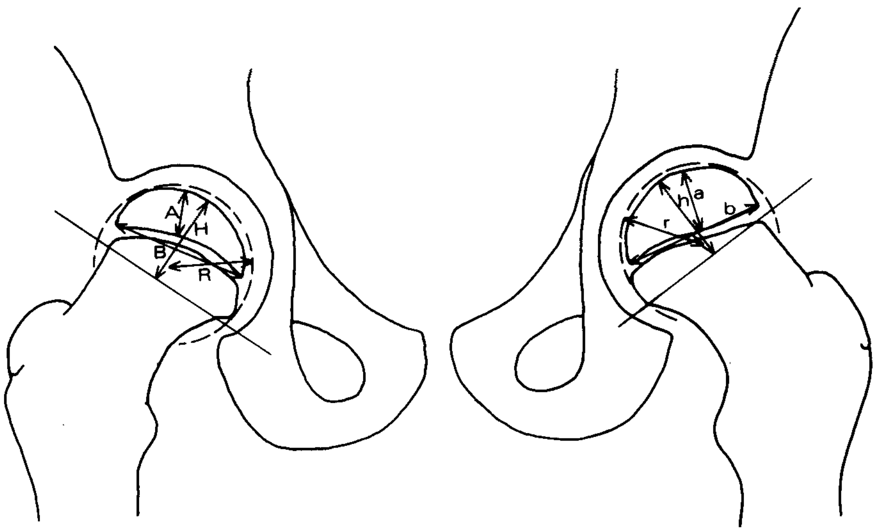

Fig. 11: Sites of measurement on the involved hip (right) and uninvolved hip (left).

Calculation of quotients and ratio between epiphysis and entire head.

Epiphyseal quotient: $\dfrac{\frac{A}{B} \times 100}{\frac{a}{b} \times 100} \times 100 = \dfrac{A \times b}{B \times a} \times 100$

Joint surface quotient: $\dfrac{\frac{2\pi R\ H}{2\pi R^2} \times 100}{\frac{2\pi r\ h}{2\pi r^2} \times 100} \times 100 = \dfrac{H \times r}{R \times h} \times 100$

Radius quotient: $\dfrac{R}{r} \times 100$

Epiphyseal surface in relation to cartilage-covered surface of the head:

Involved side: $\dfrac{2\pi\ r\ a}{2\pi\ r\ h} = \dfrac{a}{h} = \dfrac{17\ mm}{25\ mm} = 0.68$

Uninvolved side: $\dfrac{2\pi\ R\ A}{2\pi\ R\ H} = \dfrac{A}{H} = \dfrac{14\ mm}{25\ mm} = 0.56$

Epiphyseal volume in relation to volume of entire head:

Uninvolved side: $\dfrac{\frac{\pi}{3}\ a^2\ (3r-a)}{\frac{\pi}{3}\ h^2\ (3r-h)} = \dfrac{17^2\ (66-17)}{25^2\ (66-25)} = 0.55$

Involved side: $\dfrac{\frac{\pi}{3}\ A^2\ (3R-A)}{\frac{\pi}{3}\ H^2\ (3R-H)} = \dfrac{14^2\ (66-14)}{25^2\ (66-25)} = 0.40$

NORMAL VALUES:

In order to be able to apply these measuring methods later for grading a pathological material, I investigated which variations arose in measuring a normal series. This normal series comprises 66 randomly selected children with no hip disease, whose hip joints were X-rayed without showing any abnormalities. The age range is 2 - 13 years. They may be divided into 3 age groups, 22 under 5 years, 32 between 5 and 8, and 12 over 8 years of age.

Table 8. Distribution of indices and quotients in a normal series:

	5 years		5 - 8 years		8 years		Total	
EpI:	22	(100%)	32	(100%)	12	(100%)	66	(100%)
66 - 70	6	(27%)					6	(9%)
61 - 65	4	(18%)					4	(6%)
56 - 60	4	(18%)	2	(6%)			6	(9%)
51 - 55	5	(23%)	8	(25%)	1	(8%)	14	(21%)
46 - 50	3	(14%)	14	(44%)	5	(42%)	22	(33%)
41 - 45			8	(25%)	4	(33%)	12	(18%)
36 - 40					2	(17%)	2	(3%)
JsI:								
81 - 85	2	(9%)					2	(3%)
76 - 80	3	(14%)	1	(3%)			4	(6%)
71 - 75	8	(36%)	10	(31%)			18	(27%)
66 - 70	7	(32%)	15	(15%)	5	(42%)	27	(41%)
61 - 65			6	(19%)	6	(50%)	12	(18%)
56 - 60	2	(9%)			1	(8%)	3	(5%)
EpQ:								
96 - 100	17	(77%)	19	(59%)	9	(75%)	45	(68%)
91 - 95	3	(14%)	11	(35%)	2	(17%)	16	(24%)
86 - 90	2	(9%)	2	(6%)	1	(8%)	5	(8%)
JsQ:								
96 - 100	17	(77%)	29	(91%)	12	(100%)	58	(88%)
91 - 95	4	(18%)	3	(9%)			7	(11%)
86 - 90	1	(5%)					1	(1%)
RaQ:								
100 - 105	19	(86%)	30	(94%)	12	(100%)	61	(92%)
106 - 110	3	(14%)	2	(6%)			5	(8%)

All femoral heads proved spherical when measured with the template, with a radius variation of $\pm$ 1 mm. The distribution of the epiphyseal index, joint surface index, epiphyseal quotient, joint surface quotient, and radius quotient is apparent from Table 8.

This table shows that the distribution of the two indices varied with age, both falling with increasing age. Calculation of the quotients revealed that especially the RaQ, but also the JsQ, differed by more than 5% from 100 in only a very low percentage. The appearance of the epiphyses in the two hips differed rather more, but all had an EpQ over 85. The results in this normal series are in exact conformity with Mose's calculation of the epiphyseal index and its age variations in 363 normal hips and Meyer's calculation of the quotients in 80 normal hips.

SIGNIFICANCE OF X-RAY PROJECTION:

Assessment of capital shape into spherical and irregular has to be done on the basis of films in two views, approximately at right angles to each other e.g. anteroposterior and Lauenstein. It is questionable whether calculation of the quotients on the AP views only can reflect the state of the 3-dimensional head.

To study this aspect I performed all measurements in all 4 series on anteroposterior as well as Lauenstein films. On the basis of the two sets of measurements the mean quotients were calculated, using the mean value of the two measurements of epiphyseal height, epiphyseal width, and capital height, as well as shortest and longest radius. The curves in Figs. 12, 13, and 14 exemplify the small variation in the mean quotients as compared with the anteroposterior quotients.

The conclusion must be: For comparing different series or for analysing the results of individual series, calculation of epiphyseal quotients, joint surface quotients, and radius quotients on the basis of anteroposterior films is sufficient to reflect the status of the spherical heads.

SIGNIFICANCE OF MEASUREMENT ACCURACY:

If strict criteria are not set up for the points of measurement the quotients may exhibit pronounced differences. Even with the

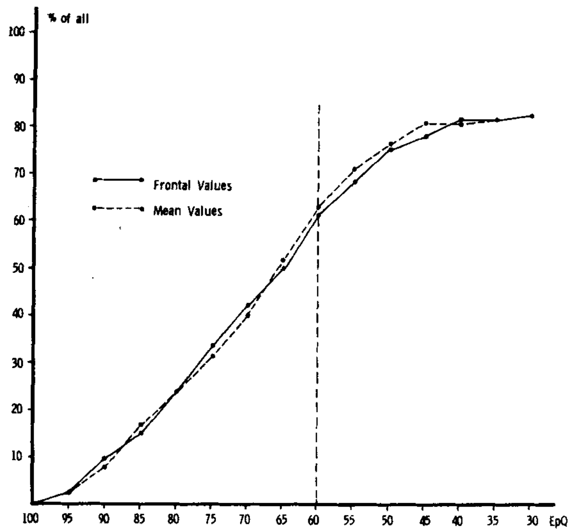

Fig. 12: Distribution of epiphyseal quotients in the wheelchair series on anteroposterior views and according to calculations of the mean.

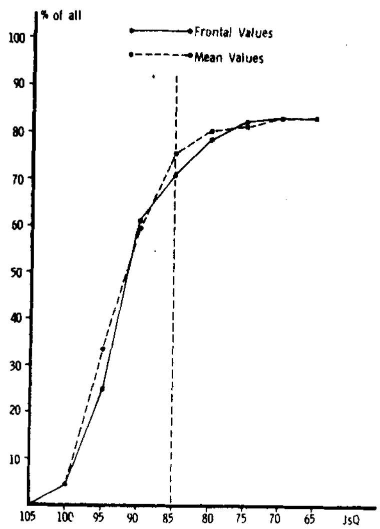

Fig. 13: Distribution of joint surface quotients in the traction in bed series on AP films and by calculations of the mean.

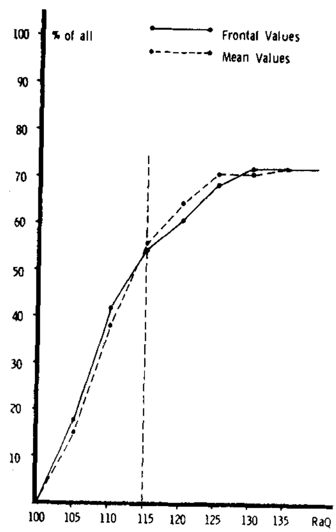

Fig. 14: Distribution of radius quotients in the bed rest series on AP films and by calculations of the mean.

present goal of an accuracy of 1 mm, there are limits to the accuracy with which the results can be classified.

The result in Case 35 may serve as an illustrative example. This was a girl aged 12½ years in whom the femoral head had become spherical, with EpQ 56, JsQ 94, and RaQ 111. If the measurements included in the quotients are altered by 1 mm in one hip, e.g. the epiphyseal height by -1 mm and the radius -1 mm on the involved side, the result is still spherical shape, but now EpQ 51, JsQ 99, and RaQ 105. An alteration of the two values by +1 mm alters the quotients to EpQ 62, JsQ 90, and RaQ 116. Thus, a variation of ± 1 mm in the measurement affords a variation of ± 5 - 6% in the quotients. Alteration of various measurements in both hips by ± 1 mm, with additive effect, may shift the result by ± 10%. Furthermore, age is a factor, a variation of 1 mm causing a relatively greater change in the result the younger the patient, with consequently lower measurements on the bone.

Grading of the results at intervals of 5 quotient per cent, as done by Meyer (1966), eliminates the greater part of the inaccuracy arising because the measurements cannot be made with an accuracy within 1 mm. However, when fixing a given borderline value, e.g. EpQ 60 for the classification "good", some reserve must be attached to the numerical value fixed as "good".

COMPARISON OF DIFFERENT INVESTIGATORS' MEASUREMENTS OF THE SAME SERIES:

As already mentioned repeatedly above, several authors have tried to compare their results with those of others by using the same principle of assessment. If such comparisons are to acquire any real value, it must be ascertained that the criteria of assessment and grading have been identical. This presupposes methods of assessment as objective as possible.

By the present measuring methods the problem of comparison was studied, as 3 of the series have been measured also by Meyer. His measurements and mine were performed independently and without a knowledge of each other's results until all the measurements had been completed. In addition, the bed rest series was assessed by Mose (1964) as far as the epiphyseal quotients and the attainment of sphericity are concerned.

Comparison Concerning Spherical Shape:

There is satisfactory conformity in this assessment (Table 9). A very few heads, on the limit to spherical shape, were assessed differently by the individual investigators, but the number in which both or all three agree on sphericity is only 2 - 5% lower than the best individual assessment.

Table 9. Assessment of sphericity when several investigators have assessed the same series:

	Wheelchair series 114 pts.	Bed rest series 79 pts.	Traction in bed series 113 pts.
J. Lauritzen	94 (82.5%)	57 (72.2%)	94 (83.2%)
J. Meyer	97 (85.0%)	58 (73.5%)	97 (85.8%)
Both investigators	91 (79.9%)	56 (71.0%)	93 (82.3%)
K. Mose		58 (73.5%)	
All 3 investigators		54 (68.4%)	

Comparison Concerning Quotients:

The quotient results are plotted on Figs. 15, 16, and 17. As in Figs. 12, 13, and 14, these are summation curves signifying how high a percentage of the entire series attained a quotient value better than the value stated on the abscissa. Since of all the heads only the spherical ones were calculated for quotient, all the curves end at that percentage of the series which proved to be spherical. The vertical broken lines indicate the limit of a sufficiently good quotient value. This limit was selected in conformity with Mose and Meyer.

The curves selected (one from each series and one concerning each quotient) are merely examples of the slight difference between the results found by the various investigators. It applies to all 3 quotients in all 3 series that the curves are nicely parallel and

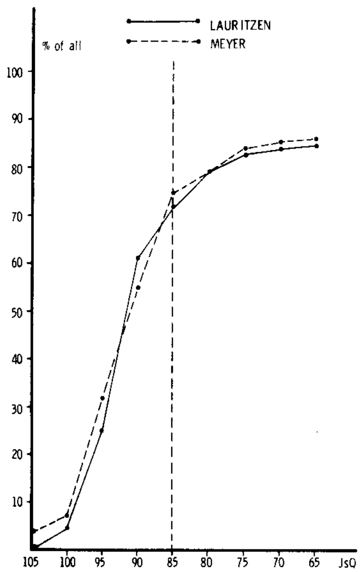

Fig. 15: Distribution of epiphyseal quotients in the bed rest series of 3 different investigators' measurement on AP films.

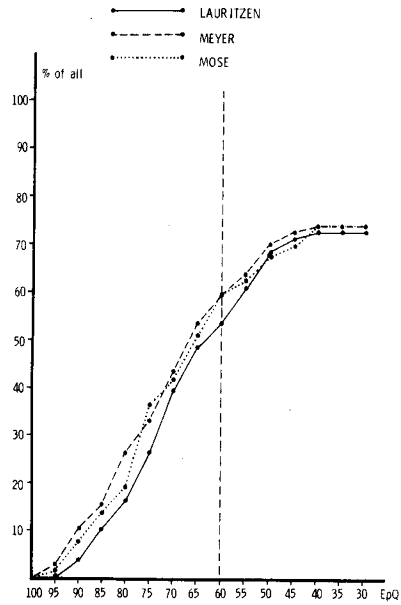

Fig. 16: Distribution of joint surface quotients in the traction in bed series of 2 different investigators' measurements on AP films.

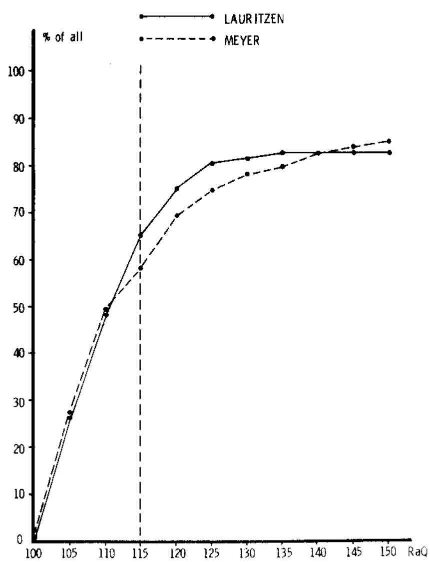

Fig. 17: Distribution of radius quotients in the wheelchair series of 2 different investigators' measurements on AP films.

seldom vary by more than 5%, and never by more than 8% at the level of the borderline value. This difference is somewhat greater than the difference seen at a measurement accuracy of 1 mm, but it corresponds to the margin of error that Harrison & Menon (1966) allowed in their use of the "comprehensive quotient", even although the measuring points were selected according to somewhat different criteria by the various investigators. The difference between these criteria is eliminated by the fact that the same criteria were used on both sides. Owing to the uncertainty of the results found by two investigators, however, it is not permissible, as done by Steinhauser (1970), to claim superiority of one therapeutic method above another on the basis of a few per cent more good results in one group.

CONCLUSION:

In conclusion, it may be stated concerning the measuring methods used and the accuracy with which they may be employed:

When one investigator uses the template as stated, for assessing on films in both views the osseous shape of the entire cartilage-covered part of the femoral head, he will assess, with a margin of error of about 5%, the same heads as spherical as will another investigator.

Similarly, the margin of error between the calculation by two independent investigators of the EpQ, JsQ,and RaQ on the anteroposterior views will be about 5% for each quotient, and this corresponds approximately to an accuracy of 1 mm in the measurement.

When the methods are applied to comparing the results in different materials, a discrepancy of less than 5% between two materials does not prove any difference.

CHAPTER 9

IMPORTANT FACTORS AND THEIR MUTUAL RELATIONS

The main object of the present study was to investigate, on the basis of the very large number of patients, how the result has been influenced by the various factors which might be imagined to affect it. In order to be able to compare the 4 series later, I recorded the various factors separately for each. As the analysis of the results is based upon measurements on the X-ray films it was most relevant to concentrate the investigations on the 388 unilateral cases. This material is, to my knowledge, the largest one ever to be analysed. Whenever possible, the results were compared with other large materials including about 100 patients or more. (Broder (1953): 102 patients, Broder (1958): 208 patients, Cameron & Izatt (1960): 185 patients, Edgren (1965): 276 patients, Gledhill & McIntyre (1969): 98 patients, Hauge (1957): 100 patients, Jacchia & Faldini (1967): 186 patients, Katz (1967): 283 patients, Kemp & Boldero (1966): 258 patients, Levy & Girard (1942): 102 patients, Mose (1964): 257 patients, Peić (1962): 177 patients, Taussig & Héripret (1969): 275 patients, Wansbrough et al. (1959): 129 patients, Wilk (1965): 186 patients).

Before analysing the influence of the various factors upon the result, I investigated the mutual dependence of the individual factors.

SEX AND SIDE AFFECTED:

From Table 10 it may be seen that the right and left hip were involved with equal frequency and with the same sex ratio, 81% boys and 19% girls. Apart from Levy & Girard (1942), who reported 91% boys, all other workers have had a sex ratio within the limits of the present 4 series. The sex ratio was the same for both sides, unlike that in Peić's (1962) material.

Table 10: Sex ratio and side affected:

		Boys:		Girls:	
Right	199	161	(81%)	38	(19%)
Left	189	153	(81%)	36	(19%)
Total	388	314	(81%)	74	(19%)
Wheelchair	114	93	(82%)	21	(18%)
Bed rest	79	60	(76%)	19	(24%)
Traction in bed	113	97	(86%)	16	(14%)
Thomas caliper	82	64	(78%)	18	(22%)

AGE DISTRIBUTION:

The patients' age refers to that at which treatment was instituted at the centre concerned. In the great majority of cases this age corresponds to the age group at which the disease was diagnosed, although some of the patients had been treated for a short time elsewhere. Ståhl (1948) felt that on the basis of the radiological stage at diagnosis it was possible to calculate how many months had elapsed since the onset. In my opinion, such a back-calculation is extremely uncertain, and I also do not consider it possible to calculate from data given concerning the duration of symptoms. Besides, it seems much more relevant to reckon from the age at institution of treatment, as this must be of most interest in analysing the result of the treatment.

Fig. 18 sets out the age distribution graphically. The age summit for the girls is ½ - 1 year lower than that for the boys.

For practical reasons I divided the unilateral cases into 3 age groups, viz.:

<u>Under 5 years</u>, when the treatment was instituted before the patient's 5th birthday.

<u>5 - 8 years</u> from the 5th to the 9th birthday, and

<u>over 8 years</u> after the 9th birthday

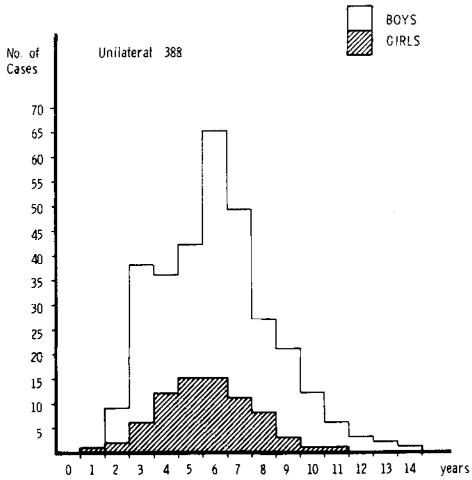

Fig. 18: Age distribution of boys and girls in the 388 unilateral cases.

Table 11, listing the age distribution in the 4 series, shows that the wheelchair series and the traction in bed series included the relatively largest number of the youngest patients and the wheelchair series, in particular, rather few of the oldest group. Thus, the mean age is lowest in the wheelchair series, 1 year older in the bed rest series, and in between in the other two series.

Table 11: Age grouping of the 4 series:

388 patients		5 years 104 (26.8%)	5 - 8 years 232 (59.8%)	8 years 52 (13.4%)	Mean age
Wheelchair	114	37 (32.5%)	69 (60.5%)	8 (7.0%)	5.54
Bed rest	79	17 (21.3%)	48 (61.2%)	14 (17.5%)	6.53
Traction in bed	113	31 (27.4%)	62 (54.9%)	20 (17.7%)	6.07
Thomas caliper	82	19 (23.2%)	53 (64.6%)	10 (13.4%)	6.20

Statistical assessment:
$X^2 = 9.62$ df = 6 $0.1 < P < 0.2$ (no significance)

There is no difference in sex ratio between the three age groups.

DURATION OF SYMPTOMS:

As I wished to investigate the relationship of the duration of symptoms to the clinical and radiological course, and its possible influence upon the therapeutic result,the data in this respect were also recorded in all 4 series in the unilateral cases.

Table 12: Duration of symptoms in the 4 series:

		Duration of symptoms		
		0 - 3 mos.	4 - 6 mos.	over 6 mos.
388 patients		203 (52.4%)	93 (23.9%)	92 (23.7%)
Wheelchair	114	78 (68%)	27 (24%)	9 (8%)
Bed rest	79	23 (29%)	25 (32%)	31 (39%)
Traction in bed	113	60 (53%)	23 (20%)	30 (27%)
Thomas caliper	82	42 (51%)	18 (22%)	22 (27%)

Statistical assessment:
$X^2 = 37.3$ df = 6 $P < 0.001$ (high significance)

From table 12 it is apparent that on the whole the wheelchair series had the shortest duration of symptoms. The somewhat longer duration in the bed-rest series than in the others is due to some extent to the fact that some of these patients had been started on the bed-rest therapy in other hospitals a month or two before being transferred to the Seaside Hospital at Refsnæs. For practical reasons, however, the time was calculated from the day they were admitted there. The longer duration of symptoms in the bed-rest series presumably explains the higher age distribution in this series, just as the brief duration of symptoms in the wheelchair series may explain why the age distribution is lowest in this series.

Half the patients had had symptoms for 3 months or less before being started on treatment, and the mean duration of symptoms was 4 - 5 months. This is somewhat shorter than found by Edgren (1965) in Finland during approximately the same period.

However, the data concerning the duration of symptoms can only be accepted with some reserve, as the nature of the symptoms is not alarming, and therefore the statement of their onset is uncertain. Nevertheless, the duration of symptoms shows a highly significant statistical relationship to the radiological stage at institution of treatment (vide infra).

I investigated whether the duration of symptoms bore any definite relation to age (Table 13). The age group over 8 years had had symptoms somewhat longer than the other groups, in which the distribution was exactly the same.

Boys and girls showed the same distribution of duration of symptoms.

Table 13: Relationship between duration of symptoms and age groups:

388 patients		0 - 3 mos. 203 (52.4%)	4 - 6 mos. 93 (23.9%)	over 6 mos. 92 (23.7%)
< 5 years	104	55 (53%)	24 (23%)	25 (24%)
5 - 8 years	232	127 (55%)	51 (22%)	54 (23%)
> 8 years	52	21 (40%)	18 (35%)	13 (25%)

Statistical assessment:
$X^2 = 4.62$ df = 2 P = 0.1 (no significance)

RADIOLOGICAL STAGE:

Subjective Evaluation:

Since I wished to investigate, among other things, the dependence of the result upon the radiological stage at which treatment was instituted, the first X-ray films were reviewed for all 4 series. It proved possible to procure X-ray films from the very institution of treatment for all 388 unilateral cases. In all cases both hips had been X-rayed in the anteroposterior, and in the great majority also in Lauenstein's view.

Grouping into the classical stages:

I: initial stage,
II: fragmentation stage,
III: healing stage,

I found far from sufficient for a stage grouping, as 265 of the patients would in that case have to be assigned to stage I and only 75 and 19 to stages II and III respectively. 29 patients could not be classified, as the apparently mild fragmentation, without condensation, had to be classified as the special type of LCPD which is called dysplasia epiphysialis capitis femoris (vide infra).

Sub-division of the 265 patients in the initial stage on the basis of a subjective evaluation of the X-ray films resulted in the following classification:

I a: Widened joint space, but no actual condensation or flattening of the epiphysis: 39 patients.

I b: Condensation and incipient flattening: 143 patients.

I c: Condensation with flattening, but no fragmentation: 83 patients.

The objection to such a classification must be its subjective nature. With the naked eye it is not possible to distinguish definitely between true condensation and relative condensation because of reduced density of the neighbouring bony structures (groups I a and I b). It is also not possible to assess subjectively with certainty when an epiphysis ought to be classified as flattened (groups I b and I c). Furthermore, it is difficult to distinquish between groups I c and II & III. Some patients with severe condensation and flattening of the greater part of the epiphysis may show fragmentation or even regeneration laterally. Such a classification is bound to be to some extent arbitrary, and at all events it is not possible to state its accurate criteria.

Objective Evaluation By Initial Quotient:

If a staging is to be used for assessing the prognosis, I find the degree of epiphyseal flattening to be the best means of stating how deformed the femoral head is when treatment is instituted. A truly flattened epiphysis cannot be considered an early stage, even though fragmentation has not yet set in. This initial epiphyseal flattening may be stated objectively as a quotient measured in the same way as the epiphyseal quotient. To distinguish the two quotients, I have called the quotient which may be calculated from the X-ray films at the institution of treatment the initial quotient (IQ).

In all 4 series the IQ was calculated on the AP films as well as from the mean of the measurements on the AP and Lauenstein views, when the latter was available. To aim at an accuracy as great as possible, I tried to observe a measuring accuracy of ½ mm. This is of course practicable only in the earliest stages at which the epiphyseal contours are still distinct, but these are the very cases that require the greatest objectivity. The measuring points were selected according to the same criteria as in calculating the epiphyseal quotients (cf. p. 75). In the 75 patients who exhibited fragmentation already on the first X-ray film the measurement of the IQ was often very inaccurate. In these cases, however, the values were so low that it was of no interest to know them more accurately. Accordingly, they were merely collected in a group of IQ under 60.

The distribution of the initial quotients in the wheelchair series is shown in Fig. 19. It is evident that the values found by both modes of measurement gave parallel curves with very little variation.

To fix a borderline value on this curve for the criterion early treatment, I decided on the lower limit of the epiphyseal quotient for the normal series: 85.

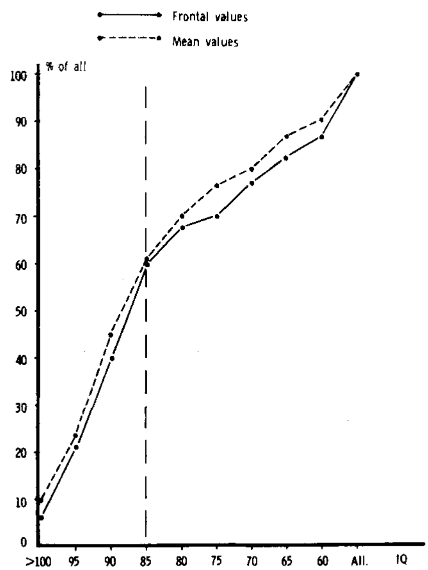

Fig. 19: Distribution of initial quotients in the wheelchair series on AP films and after calculations of mean values.

RELATIONSHIP BETWEEN STAGE AND OTHER FACTORS:

The relation between subjective description of the first X-ray film and IQ > 85:

To investigate whether an IQ limit at 85 is a relevant measure of the radiological stage in grading into early and late institution of treatment, the subjective and objective modes of assessment were related to each other. The result is shown in Table 14.

Table 14: Relationship between subjective and objective evaluation of the first X-ray films:

Subjective evaluation:		Objective eval. IQ > 85	IQ > 80
Dysplasia epiphysialis capitis femoris	29	16	22
I: Initial stage:			
a. Before condensation and flattening	39	33	38
b. Condensation and incipient flattening	143	111	136
c. Condensation with flattening	83	1	20
II: Fragmentation stage	75	1	7
III: Healing stage	19	2	2
Total	388	164	225

Thus, by selecting an IQ corresponding to the normal range we can classify 144 of the 182 subjectively early cases (I a and b) as an objectively early stage, whereas only 4 of the subjectively late cases land in the objectively early group.

If an IQ exceeding 80 is selected as the borderline value, nearly all I a and b will be included (174 out of 182), but in return an extra 19 will be assigned to group c and an extra 6 to group II. I chose the IQ range exceeding 85 from the normal series as the borderline on the motivation that in group c one case had been assessed too strictly in the subjective evaluation and that the 3 cases of groups II and III were of no significance to the result, as these 3 cases had been in a highly advanced stage, but without epiphyseal flattening, when treatment was instituted. Indeed, all three obtained a good result. The advantages of this objective staging are evident as compared with previously reported subjective classifications, even though the method has not proved satisfactory in distinguishing the group dysplasia epiphysialis capitis femoris. These cases are difficult to measure accurately, and only a little more than half have been included in the early stage. However, the prognosis in this special type of the disease is always favourable, as will be demonstrated below.

Relationship Between Stage and Age:

From Table 15 it is apparent that on the whole the youngest patients showed the lowest initial quotients. This probably indicates merely that a few mm flattening of the small epiphyses means more than in the epiphyses of the older children.

Table 15: Relationship between stage and age:

388 patients		IQ > 85 164	(42%)	IQ ≤ 85 224	(58%)
< 5 years	104	39	(37%)	65	(63%)
5 - 8 years	232	98	(42%)	134	(58%)
> 8 years	52	27	(52%)	25	(48%)

Statistical assessment:
$X^2 = 2.96$ df = 2 $0.2 < P < 0.3$ (no significance)

Table 16: Relationship between stage and duration of symptoms:

388 patients		IQ 85 164	(42%)	IQ 85 224	(58%)
0 - 3 months	203	117	(57%)	86	(43%)
4 - 6 months	93	34	(37%)	59	(63%)
> 6 months	92	13	(14%)	79	(86%)

Statistical assessment:
$X^2 = 50.74$ df = 2 $P < 0.001$ (high significance).

Relationship Between Stage and Duration of Symptoms:

As might be expected, there was an extremely clear relationship between the two IQ groups and the duration of symptoms (Table 16). The majority of patients with a brief duration of symptoms were among those with an IQ exceeding 85 and in return the majority with IQ's below 85 among those with symptoms for more than 6 months. Similarly, Broder (1953), among patients with a duration of symptoms of up to 3 months, found that 80% had not reached the fragmentation stage.

The difference in duration of symptoms between the four series (Table 12) is apparent also in a corresponding difference between the IQ groups (Table 17).

Table 17: Staging in the 4 series:

		IQ > 85		IQ ≤ 85	
388 patients		164	(42.3%)	224	(57.7%)
Wheelchair	114	68	(59.7%)	46	(40.3%)
Bed rest	79	25	(31.7%)	54	(68.3%)
Traction in bed	113	45	(39.8%)	68	(60.2%)
Thomas caliper	82	26	(31.7%)	56	(68.3%)

Statistical assessment:
$X^2 = 21.79$ df = 3 $P < 0.001$ (high significance)

RADIOLOGICAL TYPE AND DEGREE OF CHANGES:

The further radiological course has developed in a varied way, so that it is justified to classify the cases by the degree of changes arising in the bone:

Abortive cases:

Barbieri & Palminteri (1967) reported that among 96 patients they had observed radiological variations from extremely mild changes with slight marginal defects up to severe total destructions in the epiphysis. The mildest forms are often called abortive cases of LCPD. In a review of 208 LCPD patients Katz (1965) found such very small translucencies of the epiphyseal contour in 16%. Most often he found only one defect, and visible only in one view. The change was asymptomatic, occurred almost exclusively in boys and at a younger age than the true LCPD changes. These epiphyses always ended in perfect healing. The cause of these changes is unknown, but Emr & Komprda (1968) interpreted them as variations in the development of ossification. They occurred more often among LCPD patients than among healthy children or children with transient synovitis. The sex and age distribution was like that found by Katz.

Dysplasia epiphysialis capitis femoris (D.e.c.f.).

The transition from the abortive cases to the changes which Pedersen (1960) and Meyer (1964) have called d.e.c.f. is undefinable. These changes too were found more often among the youngest age group, but the sex ratio was the same as for LCPD. They showed a definite familial predisposition, a tendency to being bilateral, and an unusually favourable prognosis. In Meyer's opinion the genesis of d.e.c.f. was a disturbance of ossification rather than avascular necrotic changes, as it was not attended with condensation or major flattening of the epiphysis. However, he adduced examples of patients with healed d.e.c.f. who later developed true LCPD changes of the femoral head.

The series which make up the present material also include such mild, uncharacteristic types. In cases with unilateral true LCPD the patients were classified as bilateral and not included in the analysis of the results, if changes of these types had persisted in the other hip for a period of approx. 6 months. Unilateral cases of these mild changes, treated as LCPD patients, make up 29 of the 388 unilateral cases or 7.5%. Here too there is a marked preponderance among the youngest age groups, **and the same predominance of boys** (table 18). The 4 series were somewhat different in the representation of d.e.c.f. cases, there being 11 in the wheelchair series, 2 in the bed rest series, 13 in the traction in bed series, and 3 in the Thomas caliper series.

Table 18: Sex and age distribution of the d.e.c.f. cases:

		Boys	Age <5 years	5-8 years	>8 years
Dysplasia epiphysialis capitis femoris	29	25 (86%)	19 (66%)	9 (31%)	1 (3%)
Total material	388	314 (82%)	104 (27%)	232 (60%)	52 (13%)

Statistical assessment of the table on age distribution:
$X^2 = 24.30$ df = 2 $P < 0.001$ (high significance)

The True LCPD Cases:

In the numerous cases in which there was occasion to follow the radiological course from the earliest stages of the disease it was extremely characteristic for the flattening to start in the anterior part of the epiphysis. This can be visualized only in the Lauenstein position. In 139 of the 388 cases (36%) there was a linear subchondral zone of translucency in the anterior part of the epiphysis, just as described by Waldenström (1934). A typical example is shown in Fig. 1. p. 5. Thereafter, collapse occurs in the area, the epiphysis narrows and shows condensation in its anterior half, and often there will be no flattening at all posteriorly.

The primary localization of the X-ray changes anteriorly has also been pointed out by Evans (1958). The subsequent fragmentation may comprise a major or minor part of the epiphysis, from less than one-third up to total epiphyseal destruction. Ralston (1961) calculated the fragmented area objectively on the basis of measurements of its extent compared with epiphyseal size. In 10 out of 43 patients (23%) he found less than 50% of the epiphyseal area to be fragmented. Others (Broder 1953, Goff 1959, Cameron & Izatt 1960, Ponseti & Cotton 1961, Mose 1964, Taussig and Hëripret 1969) have classified according to a subjective assessment into mild degrees or partial and severe degrees or total. Their materials included between 50% and 80% mild cases. All agree that the degree of the changes is of great importance to the primary healing result, the mildest degrees obtaining appreciably better results than the severe ones. Derganc (1963) even made a distinction between a benign and a malignant form of LCPD.

The present 4 series were classified subjectively into mild and severe cases. This evaluation was based upon a subjective assessment of whether less or more than half the epiphysis was fragmented at the time of maximum fragmentation.

The distribution of the degree on the individual series is apparent from Table 19. The cases of d.e.c.f. are included among the mild degrees.

Table 19: Distribution of degrees in the 4 series:

375 patients		mild 169 (45.0%)	severe 206 (55.5%)	total fragmentation 19 (5.7%)
Wheelchair	114	58 (51%)	56 (49%)	5 (4%)
Bed rest	73	25 (34%)	48 (66%)	4 (5%)
Traction in bed	109	58 (53%)	51 (47%)	4 (4%)
Thomas caliper	79	28 (36%)	51 (64%)	6 (8%)

Statistical assessment:

$X^2 = 10.88$ df = 3 $0.01 < P < 0.02$ (significant)

The treatment groups showed a different distribution of degree.

From the table it is apparent that only 375 of the 388 unilateral cases were assessed. The remaining 13 had such late changes when treatment was instituted that the degree was unassessable.

Several workers, int. al. Slocum (1941), O'Garra (1959), Edgren (1965), and Eyring et al. (1965) have included the degree of metaphyseal changes in the assessment of severity, finding a parallelism between the degree of metaphyseal and epiphyseal changes. In the present wheelchair series the degree of metaphyseal changes was assessed as mild in 78 cases (68%) and severe, with marked cyst formation, in 36 (32%). 29 of these 36 patients also had severe degrees of epiphyseal fragmentation, whereas only 27 were found to have severe epiphyseal changes among 78 with mild metaphyseal changes. Thus, in the present material too there was a certain parallelism between the changes.

RELATIONSHIP BETWEEN DEGREE AND OTHER FACTORS:

If the degree of fragmentation is related to the stage, in terms of the IQ or the duration of symptoms (Tables 20 and 21), we find a marked dependency. Patients with the longest duration of symptoms, especially those with epiphyseal flattening, have more often developed a severe degree, whereas age (Table 22) has been of no consequence. In particular, the older patients have not shown more severe changes than the youngest ones.

Table 20: Relationship between degree and stage:

		Mild	Severe
375 patients		169 (45%)	206 (55%)
IQ > 85	163	100 (61%)	63 (39%)
IQ ≤ 85	212	69 (33%)	143 (67%)

Statistical assessment:
$X^2 = 30.87$ df = 1 $P < 0.001$ (high significance)

Table 21: Relationship between degree and duration of symptoms:

		Mild	Severe
375 patients		169 (45%)	206 (55%)
≤ 3 mos.	198	103 (52%)	95 (48%)
4 - 6 mos.	93	42 (45%)	51 (55%)
> 6 mos.	84	24 (29%)	60 (71%)

Statistical assessment:
$X^2 = 13.10$ df = 2 $0.001 < P < 0.01$ (high significance)

Table 22: Relationship between degree and age:

375 patients	Mild 169 (45%)	Severe 206 (55%)
< 5 years 103	43 (42%)	60 (58%)
5 - 8 years 222	97 (44%)	125 (56%)
> 8 years 50	29 (58%)	21 (42%)

Statistical assessment:
$X^2 = 4.01$ df = 2 $0.1 < P < 0.2$ (no significance)

Table 23: Relationship between degree and non-weightbearing period:

375 patients	Mild 169 (45%)	Severe 206 (55%)
≤ 18 mos. 81	49 (60%)	32 (40%)
19 - 30 mos. 250	109 (44%)	141 (56%)
> 30 mos. 44	11 (25%)	33 (75%)

Statistical assessment:
$X^2 = 15.16$ df = 2 $P < 0.001$ (high significance)

If the assessment of the degree is related to the period of non-weightbearing which was deemed necessary (Table 23), it is obvious that the severe degrees have more often required a longer period and the mild degrees correspondingly a shorter period of non-weightbearing.

DURATION OF RADIOLOGICAL CHANGES:

In the wheelchair series the period from the onset of fragmentation until regenerative processes again predominated could be assessed in 93 out of the 114 unilateral cases. The period of fragmentation had lasted for an average of 10.2 months.

When relating the duration of fragmentation to the degree of fragmentation (Table 24), we find that the mild degrees only ran a slightly shorter course than the severe ones. On the other hand, there is no definite relationship between the duration of fragmentation and the age or stage groups.

Table 24: Relationship between degree and duration of fragmentation in the wheelchair series:

		Mild	Severe
93 patients		47 (51%)	46 (49%)
≤ 6 mos.	12	9 (75%)	3 (25%)
7 - 12 mos.	56	30 (54%)	26 (46%)
> 12 mos.	25	8 (32%)	17 (68%)

Statistical assessment:
$X^2 = 6.52$ df = 2 $0.02 < P < 0.05$ (doubtful significance)

DURATION OF THE DISEASE AND ITS RELATIONSHIP TO OTHER FACTORS:

The duration of the entire radiological course, from the institution of treatment until the time of primary healing 1 - 4 years after the treatment had been discontinued, was recorded in all 114 unilateral cases of the wheelchair series. This period was designated the duration of the disease and related to the duration of fragmentation, the age, stage, and degree groups, as well as the treatment period and the strictness with which the wheelchair regimen was observed (Tables 25, 26, 27, 28, 29, and 41). The lenght of the fragmentation period as well as the entire duration of the disease in the wheelchair series is in exact conformity with the findings of Edgren (1965).

A classification results in a relatively small number of patients in each group, but nevertheless the calculations show some factors concerning the relations with fair certainty.

Age does not appear to have any influence upon the duration of the disease (Table 25).

The stage, in terms of epiphyseal flattening, has an uncertain influence upon the duration of the disease, even though patients with least flattening had on the whole a shorter duration of the disease (Table 26).

The degree plays a more important role, those of severest degree also having the longest duration of the disease (Table 27). The influence of the stage presumably manifests itself by way of the degree.

If the fragmentation period was particularly long (>12 mos.), the entire duration of the disease was also longest (Table 28).

Cases in which non-weightbearing had to be continued for a very long time (>30 mos.) also had had a very long duration of disease, and reversely those with the shortest period of non-weightbearing corresponded to a short duration of disease (Table 29).

Table 25: Relationship between duration of disease and age groups:

114 patients		< 4 years 52 (45%)	4 - 6 years 45 (40%)	> 6 years 17 (15%)
≤ 5 years	37	20 (54%)	10 (27%)	7 (19%)
5 - 8 years	69	28 (41%)	31 (45%)	10 (14%)
> 8 years	8	4 (50%)	4 (50%)	0 (0%)

Statistical assessment:
$X^2 = 4.80$ df = 4 $0.2 < P < 0.3$ (no significance)

Table 26: Relationship between duration of disease and stage groups:

114 patients		< 4 years 52 (45%)	4 - 6 years 45 (40%)	> 6 years 17 (15%)
IQ >85	68	36 (53%)	26 (38%)	6 (9%)
IQ ≤ 85	46	16 (35%)	19 (41%)	11 (24%)

Statistical assessment:
$X^2 = 6.24$ df = 2 $0.02 < P < 0.05$ (doubtful significance)

Table 27: Relationship between duration of disease and degree groups:

114 patients		< 4 years 52 (45%)	4 - 6 years 45 (40%)	> 6 years 17 (15%)
Mild	58	38 (65%)	19 (33%)	1 (2%)
Severe	56	14 (25%)	26 (46%)	16 (29%)

Statistical assessment:
$X^2 = 25.37$ df = 2 $P < 0.001$ (high significance)

Table 28: Relationship between duration of disease and fragmentation period:

93 patients		< 4 years 39 (42%)	4 - 6 years 39 (42%)	> 6 years 17 (15%)
≤ 6 mos.	12	6 (50%)	5 (42%)	1 (8%)
7 - 12 mos.	56	29 (52%)	21 (37%)	6 (11%)
> 12 mos.	25	4 (16%)	13 (52%)	8 (32%)

Statistical assessment:
$X^2 = 11.73$ df = 4 P = 0.02 (significant)

Table 29: Relationship between duration of disease and duration of non-weightbearing:

114 patients		< 4 years 52 (45%)	4 - 6 years 45 (40%)	> 6 years 17 (15%)
≤ 18 mos.	23	18 (78%)	5 (22%)	0 (0%)
19 - 30 mos.	67	30 (45%)	28 (42%)	9 (13%)
> 30 mos.	24	4 (17%)	12 (50%)	8 (33%)

Statistical assessment:
$X^2 = 21.38$ df = 4 $P < 0.001$ (high significance)

CONCLUSION OF CLINICAL AND RADIOLOGICAL ANALYSIS:

1) LCPD is a disease occurring at the age of 2 - 13 years, with a marked peak among 5 - 7-year-olds.

2) 10 - 20% develop the disease in both hips, and these patients are generally younger than those with unilateral disease (Chapter 12),

3) There is a preponderance of boys (about 80%)

4) There is a pronounced familial predisposition.

5) Symptoms are so mild that months may elapse before the diagnosis is made.

6) Restriction of motion in the involved hip usually affects abduction and rotation.

7) An initial epiphyseal quotient over or under 85 is applicable in practice as an objective basis of staging at the time of diagnosis.

8) Calculation of this initial quotient (IQ) need only be made on the anteroposterior films.

9) The degree of epiphyseal flattening, measured by the IQ, increases in most cases with the duration of clinical symptoms.

10) Radiological changes of the femoral head may be of extremely varying degree.

11) The mildest degrees, "abortive cases" and dysplasia epiphysialis capitis femoris, probably represent a separate type of the disease, found in about 7.5% of patients with LCPD, chiefly among the youngest ones.

12) The degree becomes most severe in patients who present for treatment at the stage of flattening and also if they are

badly protected from weightbearing.

13) The severe degrees run a longer radiological course and require a longer period of non-weightbearing.

14) The quality of protection from weightbearing influences the duration of the disease which is shortened when the patients are most effectively protected from weightbearing (Chapter 11).

CHAPTER 10

INFLUENCE BY THE VARIOUS FACTORS UPON THE RESULT

PREVIOUS INVESTIGATIONS:

The great majority of authors who have studied the results obtained in LCPD materials have found a relationship between one or several of the named factors and the results. However, there is much disagreement as to which factors are of any importance at all and which ones are most important. Both Broder (1953) and Mose (1964) found the result to be influenced by sex, age, stage, degree, and therapeutic method. They shere Catterall's (1971) view that the results are poorer in girls than in boys. Not many have tried to assess the degree, but those who have report that the more severe and widespread the processes of fragmentation the poorer the results (Chung & Moe 1965, Derganc 1963, Eaton 1967, Kemp & Boldero 1966, and Ratliff 1956).

Most authors have found a distinct correlation to age, the youngest patients deriving the best results, and to stage, the earliest institution of treatment giving the best results. A few claim, however, that age plays no role (Chung & Moe 1965, Eyring et al. 1965, Harrison & Menon 1966, and Ralston 1961), and others have found no correlation to stage (Eaton 1967, Jones 1959, Katz 1967, and Taussig & Héripret 1969). Hogg (1965) found that neither age nor stage exerted any influence.

Such an extent of disagreement in these fields is surprising. However, it must be borne in mind that the assessment of stage and degree is most often based upon a subjective estimate, that different methods have been used for judging the results, some of which are also based partially upon a subjective estimate, and that not all materials are sufficiently large for the correlations to be definitely manifest.

ASSESSMENT OF THE PRESENT RESULTS AS EXCELLENT, GOOD, FAIR, AND POOR:

With a sufficiently large material, and using objective criteria whenever this was possible, I investigated the influence of the various factors upon the result.

The problem was primarily

(1) to arrive at a manner of summarizing the parameters, on the basis of the measuring methods, into a **simplified** grading of the results, and thereafter

(2) to try accounting for the influence of the individual factors upon the result.

Re (1):

Considering what has been stated concerning the long-term prognosis of the disease, it seemed reasonable to use healing of the femoral head in spherical shape as a measure of a good result, calling the remainder poor results. However, such a classification would be too simple and too crude. It is also necessary to form an impression as to what sort of spherical head has formed. The result is of course not equally satisfactory with a near-normal head, an hemispherical caput magnum, or any degree in between. However, the limit to the poor results would be very sharp, and in fact it is not. A number of the heads having e.g. a 2 - 4 mm radius variation may easily have a regular and smooth surface on that part of the joint surface which is of any significance, although they belong to what was previously called cylindrical shape, egg shape, or mushroom shape. A radius variation exceeding 4 mm, on the other hand, nearly always co-exists with a decidedly irregular shape (cap shape or angular shape). To comply with the requirement of a sub-division of the spherical heads, I used the three quotients, each of which gives its information about the condition of the head.

The epiphyseal quotient (EpQ) tells us how great a part of the head the epiphysis constitutes. Since the disease affects primarily the epiphysis, it is suitable to include a measure of epiphyseal regeneration in the assessment. A quotient exceeding 85, corresponding to a normal material, is too exacting a demand which can be fulfilled only by the very best cases. I felt it was suitable to fix the limit at 60. This is also in conformity with Mose (1964) who found a good parallelism between sphericity and an EpQ exceeding 60.

The joint surface quotient (JsQ) signifies the size of the cartilage-covered part of the head, which is indeed also relevant to include in the assessment, and so is the radius quotient (RaQ) which represents the degree of caput magnum. In the case of the two latter quotients I found, like Meyer (1966) before me, the limits of JsQ = 85 and RaQ = 115 from the normal material to be a suitable demand.

Geometrically the three quotients need not vary in relation to each other. True, the radius is included in the formula of RaQ as well as JsQ, but the heights in the segments of the spheres may vary independently of the radii, whereas other variables are used in the calculation of the EpQ. Accordingly, it need not by any means be the same patients that obtain values on the favourable side of the limits for all three quotients. However, Schiller & Axer (1972) found a caput magnum more often where the EpQ was low.

In the present analysis, however, there proved to be a relatively good agreement between the borderline values chosen, although a number of the heads could of course only fulfill one or two of the quality demands.

If patients attain a result which shows at the same time a JsQ and a RaQ within the range of the normal material and an EpQ above 60, this must be considered optimal. I, therefore, decided to grade the results as follows:

<u>EXCELLENT</u>: All spherical heads whose EpQ exceeded 60, JsQ exceeded 85, and the RaQ was below 115.

<u>GOOD</u>: All other spherical heads.

<u>FAIR</u>: Irregular heads with a radius variation between 2 and 4 mm.

<u>POOR</u>: Very irregular heads with a radius variation exceeding 4 mm.

The results in the 388 unilateral cases were:

Excellent:	189	(48.7%)	Spherical 292 (75.3%)
Good:	103	(26.6%)	
Fair:	40	(10.3%)	Irregular
Poor:	56	(14.4%)	Very irregular

Re (2):

In finding the isolated influence of each individual factor upon the result, all the other factors have to be excluded. This is a demand which is impossible to fulfill, partly because as stated above each individual factor has to be divided into 2 or 3 groups, whose limits are arbitrary, and partly because isolating each little group from the influence of the others would give such small numerical values that it would not be possible to obtain a real assessment of the influence upon the result.

I decided, therefore, to investigate the influence of each factor upon the result without paying regard to that of the other factors. In this way it is not possible to obtain an entirely accurate assessment, but by virtue of the considerably larger groups, the method gives a very good indication of the influence exerted by each individual factor.

INFLUENCE OF SEX UPON THE RESULT:

When Table 30 is compared with Fig. 20, it will be seen that sex had no influence upon the shape of the head. However, the girls obtained hardly as good quotient values as the boys, and 15% fewer were excellent. Since there was no correlation between sex and age, stage, or degree, this difference must be real. It is possibly due to the girls' earlier growth maturation and epiphyseal closure, factors which might easily exert an influence in the age group in which the majority of patients were measured. The slight difference in the distribution of fair and poor may have been due to the same cause. In general, I feel that I can deduce the following:

CONCLUSION:

The sex factor has no influence upon the final shape of the femoral head, but some upon the way in which sphericity is regained.

INFLUENCE OF AGE UPON THE RESULT:

When Table 31 is compared with Fig. 21, it is evident that age has a marked influence upon the shape of the head, also among the irregular ones, whereas its influence upon the quotient distribution is parallel with that upon the shape. Thus 25 - 30% of all ages do attain sphericity, but not an excellent result. Mindell & Shermann (1951), assessing the result in an entirely subjective way, arrived at the same distribution in exactly the same age groups. Ebach (1968), using the same measuring methods as the present author, found an age relation almost identical with 75% spherical heads under 8 years of age and only 35% above 8 years. As regards the attainment of joint surface quotients exceeding 85 his age relation was of exactly the same magnitude as in the present material.

Table 30: Result for the 2 sexes:

388 patients		314 boys		74 girls	
Excellent	189	162	(51.6%)	27	(36.5%)
Good	103	74	(23.6%)	29	(39.2%)
Fair	40	34	(10.8%)	6	(8.1%)
Poor	56	44	(14.1%)	12	(16.2%)

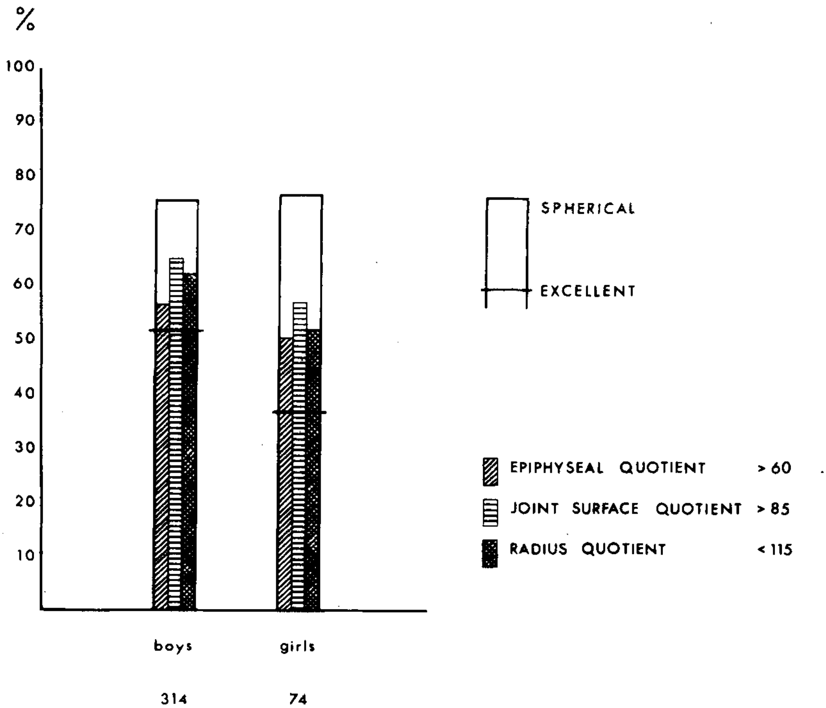

Fig. 20: Role of sex in attaining sphericity and good quotient measurements.
Boys: 69% excellent and 31% good out of 236 spherical
Girls: 48% excellent and 52% good out of 56 spherical.

Statistical assessment of shape and quotient distribution:

Spherical-Fair-Poor: $X^2 = 0.63$ df = 2 P = 0.7 (no significance)

Excellent-Good: $X^2 = 0.87$ df = 1 $0.001 < P < 0.01$ (high significance)

Table 31: Result in the 3 age groups:

388 patients		104 <5 years		232 5 - 8 years		52 >8 years	
Excellent	189	69	(66.4%)	108	(46.5%)	12	(23.1%)
Good	103	26	(25.0%)	69	(29.8%)	8	(15.4%)
Fair	40	5	(4.8%)	21	(9.0%)	14	(26.9%)
Poor	56	4	(3.8%)	34	(14.7%)	18	(34.6%)

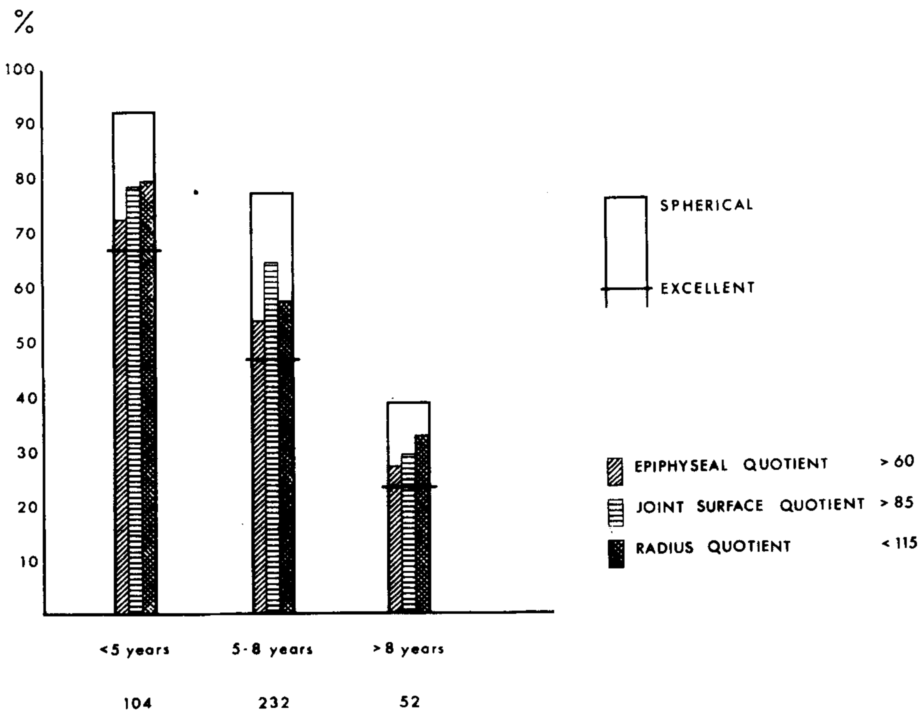

Fig. 21: Role of age in attaining sphericity and good quotient measurements.
< 5 years: 73% excellent and 27% good out of 95 spherical
5-8 years: 61% excellent and 39% good out of 177 spherical
> 8 years: 60% excellent and 40% good out of 20 spherical

Statistical assessment of shape and quotient distribution:

Spherical-Fair-Poor: $X^2 = 53.06$ df = 4 $P < 0.001$ (high significance)

Excellent-Good: $X^2 = 4.36$ df = 2 $0.1 < P < 0.2$ (no significance)

He found 64% among patients under 8 years of age and 30% among those over 8 years. In the present study the corresponding percentages were 69 and 29.

As age bore no relation to the sex or stage, and as the relationship to the distribution of degree is favourable, containing a relatively large number of mild degrees in patients over 8 years, I arrive at the following:

CONSLUSION:

The age factor has a marked influence upon the attainment of a good final shape, the younger the better, but its influence upon the way in which sphericity is regained is very uncertain.

INFLUENCE OF STAGE, DEGREE, AND TYPE UPON THE RESULT:

Owing to the distinct relationship between stage and degree, these two factors must be considered together. Apart from a slight predominance of a mild degree in the small group over 8 years of age, there was no definite relationship to sex or age.

According to Tables 32 and 33 and Figs. 22 and 23 the degree appears to have a greater influence upon the shape than has the stage, but both factors influence the quotients. The relationship calls for further analysis.

Of the 169 cases of a mild degree 29 had dysplasia (d.e.c.f.). Fig. 24 clearly shows that this special mild type of changes ends in a perfect result. However, these 29 patients did not exhibit the same relationship to the IQ as the other degree groups (cf. Table 14). They were distributed approx. equally on the two stages, 16 having an IQ exceeding 85 and 13 an IQ below or equal to 85. Accordingly, there is no need to sort off the d.e.c.f. cases in calculating the relationship between IQ and degree.

In the attempt to elucidate the influence of the stage and degree respectively upon the result, the material was divided by stage as well as by degree (Table 34, to be compared with Fig.25). This shows that it is the degree, not the stage, which influences the shape. Both factors influence the quotients. However, the degree depends upon the stage (Table 20), an early stage most often coexisting with a mild degree and a late stage with a severe degree.

Accordingly, the interesting groups are: (I) The 69 patients who showed only a mild degree of epiphyseal fragmentation, and thereby a

Table 32: Result of stage grouping

388 patients		164 IQ $>$85		224 IQ$\leq$85	
Excellent	189	101	(61.6%)	88	(39.4%)
Good	103	29	(17.7%)	74	(33.0%)
Fair	40	20	(12.2%)	20	(8.9%)
Poor	56	14	(8.5%)	42	(18.7%)

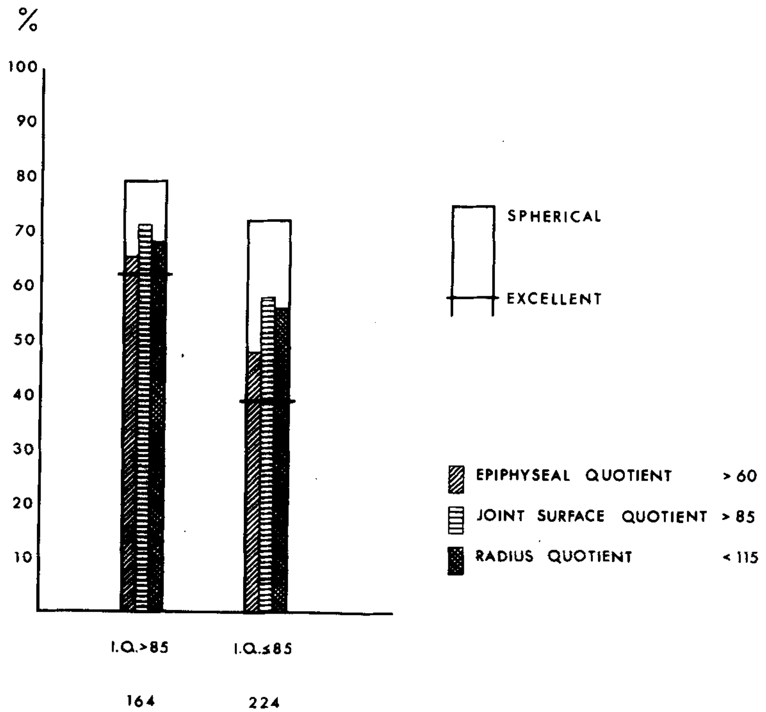

Fig. 22: Role of stage in attaining sphericity and good quotient measurements.
IQ $>$85: 78% excellent and 22% good of the 130 spherical heads
IQ $\leq$85: 54% excellent and 46% good of the 162 spherical heads.

Statistical assessment of shape and quotient distribution:

Spherical-Fair-Poor: X^2 = 8.43 df = 2 0.01$<$ P$<$0.02 (significant)
Excellent-Good: X^2 = 17.25 df = 1 P$<$0.001 (high significance)

Table 33: Result of degree grouping

375 patients		169 mild degree		206 severe degree	
Excellent	183	123	(72.8%)	60	(29.2%)
Good	98	24	(14.2%)	74	(36.0%)
Fair	39	17	(10.0%)	22	(10.7%)
Poor	55	5	(3.0%)	50	(24.1%)

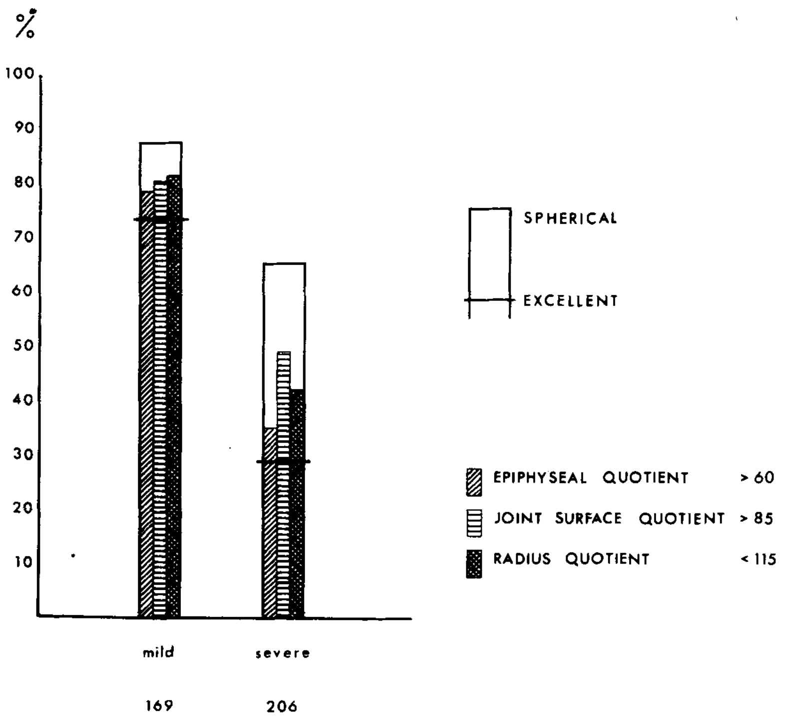

Fig. 23: Role of degree upon attainment of sphericity and good quotient measurements.
Mild degree: 84% excellent and 16% good of 147 spherical
Severe degree: 45% excellent and 55% good of 134 spherical

Statistical assessment of shape and quotient distribution:

Spherical-Fair-Poor: $X^2 = 34.94$ df = 2 $P < 0.001$ (high significance)

Excellent-Good: $X^2 = 51.27$ df = 1 $P < 0.001$ (high significance).

Result in D.e.c.f.:
Excellent 28 (96.6%), good 1 (3.4%), fair and poor 0.

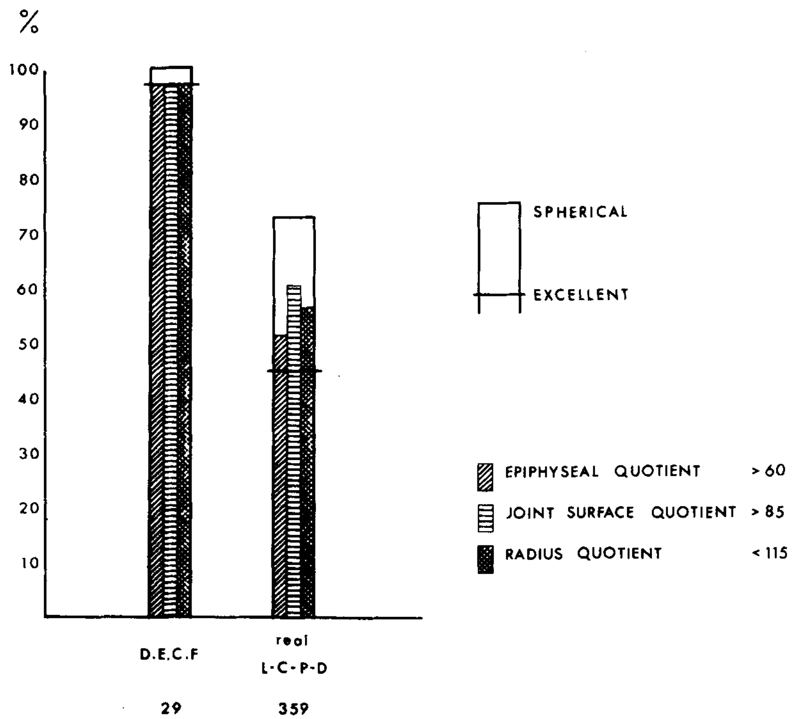

Fig. 24: Role of type in attaining sphericity and good quotient measurements.

Statistical assessment of shape and quotient distribution:
Spherical-Fair-Poor: $X^2 = 10.30$ df = 2 $P < 0.001$ (high significance
Excellent-Good: $X^2 = 14.28$ df = 1 $P < 0.001$ (high significance

Table 34: Result of stage and degree in sub-groups:

375 patients		100 mild + IQ > 85	69 mild + IQ ≤ 85	63 severe + IQ > 85	143 severe IQ ≤ 85
Excellent	183	78 (78.2%)	45 (65.2%)	22 (35.0%)	38 (26.6%)
Good	98	8 (8.0%)	16 (23.2%)	21 (33.4%)	53 (37.0%)
Fair	39	12 (12.0%)	5 (7.2%)	8 (12.7%)	14 (9.8%)
Poor	55	2 (2.0%)	3 (4.4%)	12 (18.9%)	38 (26.6%)

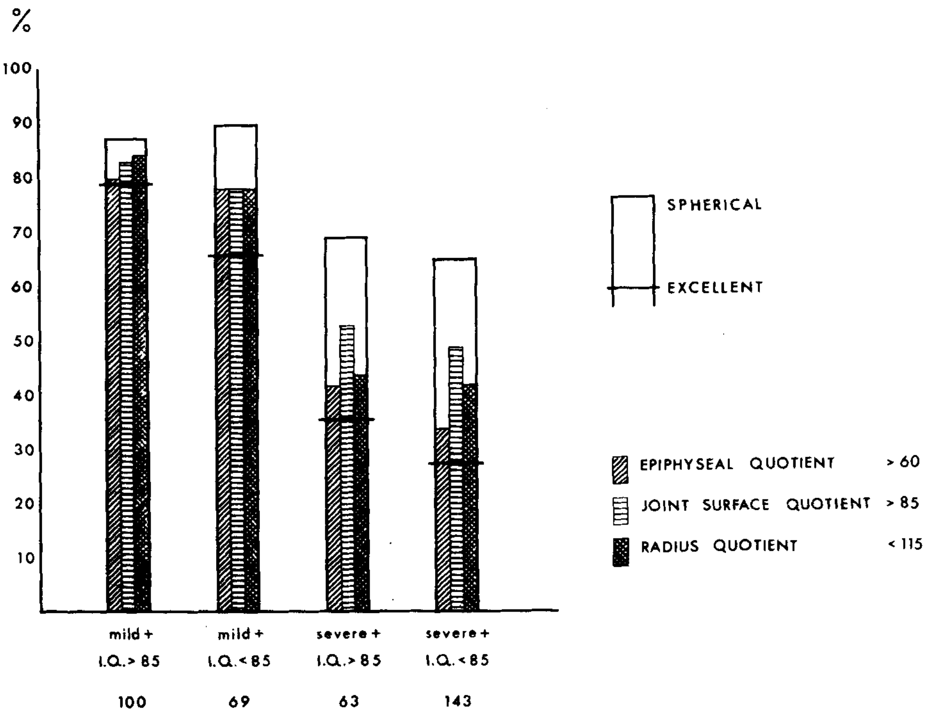

Fig. 25: Role of degree and stage respectively in attaining spher-icity and good quotient measurements.
Mild + IQ $>$ 85: 91% excellent and 9% good of the 86 spherical
Mild + IQ $\leq$ 85: 74% excellent and 26% good of the 61 spherical
Severe + IQ $>$ 85: 85% excellent and 49% good of the 43 spherical
Severe + IQ $\leq$ 85: 42% excellent and 58% good of the 91 spherical.

Statistical assessment:
Influence of stage upon shape (spherical - Fair - Poor):

When degree is mild = X^2 = 1.71 df = 1 P = 0.2 (no significance)
When degree is severe = X^2 = 1.51 df = 1 P = 0.2 (no significance)
where regard is paid to the absence of a 3-factor interaction between stage, degree, and shape. The entire significance for the influence of stage upon shape in Table 32 is due to the influence of the degree upon the shape.

Influence upon the distribution excellent - good is tested, paying regard to the presence of a 3-factor interaction between stage, degree, and quotient distribution.

Influence of stage: X^2 = 41.99 df = 1 $P < 0.001$ (high significance).

Influence of degree: X^2 = 34.61 df = 1 $P < 0.001$ (high significance).

high percentage of sphericity in spite of the fact that they were not started on treatment until epiphyseal flattening had taken place. (II) The 63 patients who exhibited a severe degree, and a correspondingly poorer result, despite the fact that they were started on treatment at an early stage. Neither sex nor age can have exerted any essential influence upon these results, and we must therefore consider the treatment factor.

Table 35: Late institution of treatment, but mild course in the 4 series:

		Wheel-chair	Bed rest	Traction in bed	Thomas caliper
IQ ≤ 85	212	46	48	65	53
IQ ≤ 85 + mild degree	69	12 (26%)	11 (23%)	29 (45%)	17 (32%)
Spherical	61	11 (92%)	9 (82%)	28 (97%)	13 (76%)
Excellent	45	6 (50%)	8 (73%)	22 (76%)	9 (16%)

From Table 35 it is apparent that the traction in bed series included the largest number of mild courses among those in whom treatment was instituted late and that the two series treated with bed rest attained a higher percentage of excellent results than the two ambulatory series in this group of patients.

Table 36:

		Wheel chair	Bed rest	Traction in bed	Thomas caliper
IQ > 85	163	68	25	44	26
IQ > 85 + severe degree	63	22 (32%)	11 (44%)	15 (34%)	15 (58%)
Spherical shape	43	15 (68%)	5 (45%)	13 (87%)	10 (67%)
Excellent	22	5 (23%)	3 (27%)	12 (80%)	2 (13%)

From Table 36 it is apparent that the Thomas caliper series included the largest number with a severe course among those given early treatment, whereas the traction in bed series is the only one to attain a high percentage of sphericity and excellent result among this group of patients.

The age distribution in all the sub-groups in Tables 35 and 36 was approximately the same and also the same as that in the entire material. Only the group IQ$\leq$85 + mild degree had a slight preponderance of the youngest age group in the traction in bed series. Nevertheless, I do not believe that the age factor can have exerted a decisive influence upon the therapeutic relationships found in the present study.

Paying due regard to the numerically small groups in these last relationship calculations, I still feel in a position to advance the following:

CONCLUSION:

The later the patient presents for treatment, the greater is the tendency to develop a severe degree of epiphyseal fragmentation, and thereby the possibility of attaining a good result is correspondingly reduced, especially as regards the shape, but also the other factors in the regeneration of the femoral head (the quotients). Moreover, this tendency seems to depend upon how effectively the patients are protected from weightbearing during the treatment.

The special, mild type "dysplasia epiphysialis capitis femoris" always attains a perfect healing result.

CHAPTER 11

INFLUENCE OF TREATMENT UPON THE RESULT

RESULT OF THE 4 NON-WEIGHTBEARING METHODS:

The results of the 4 different methods are shown in Table 37, to be compared with Fig. 26.

It will be seen that the method of treatment influences the shape of the femoral head as well as the quotients. Long-term bed rest with intermittent traction gives the most effective protection of the hip joint, whereas the Thomas caliper method gives the poorest results in all respects. Using electromyography, Boroske & Matthiass (1968) demonstrated that the Thomas caliper affords considerably less than the 80% protection from pressure of the hip muscles which have previously been considered its efficacy.

Although no one has used the present grading of the results earlier, some comparison may be made with the results of others, especially where the percentage of sphericity is concerned (excellent + good).

In his follow-up study from 1949 Sundt found 11 spherical heads among 88 almost untreated patients protected from weightbearing for a very short time. This corresponds to 12.5%. Helbo (1953) found 20% spherical heads in two series, one untreated and the other one protected from weightbearing for only a short time, whereas among his patients treated by long-term non-weightbearing 80% had spherical heads.

Using the Comprehensive Quotient, which affords no information about sphericity, Stamp et al. (1959) found 30% of the untreated cases to be in the excellent or good group, but stated that these were mild cases. In a clinical-radiological assessment Catteral (1971) found that 27 out of 46 untreated cases (59%) ended up as good, which is the same result as in his treated group.

Such a wide variation in the findings merely shows the insufficiency of the evaluation methods and the role of lacking data concerning the composition of the untreated series as regards e.g. age and stage.

Table 37: Results in the 4 treatment groups:

388 patients		Wheel 114 chair	Bed 79 rest	Traction 113 in bed	Thomas 82 caliper
Excellent	189	60 (52.7%)	37 (46.8%)	72 (63.7%)	20 (24.4%)
Good	103	34 (29.8%)	20 (25.3%)	22 (19.5%)	27 (32.9%)
Fair	40	13 (11.4%)	10 (12.7%)	8 (7.1%)	9 (11.0%)
Poor	56	7 (6.1%)	12 (15.2%)	11 (9.7%)	26 (31.7%)

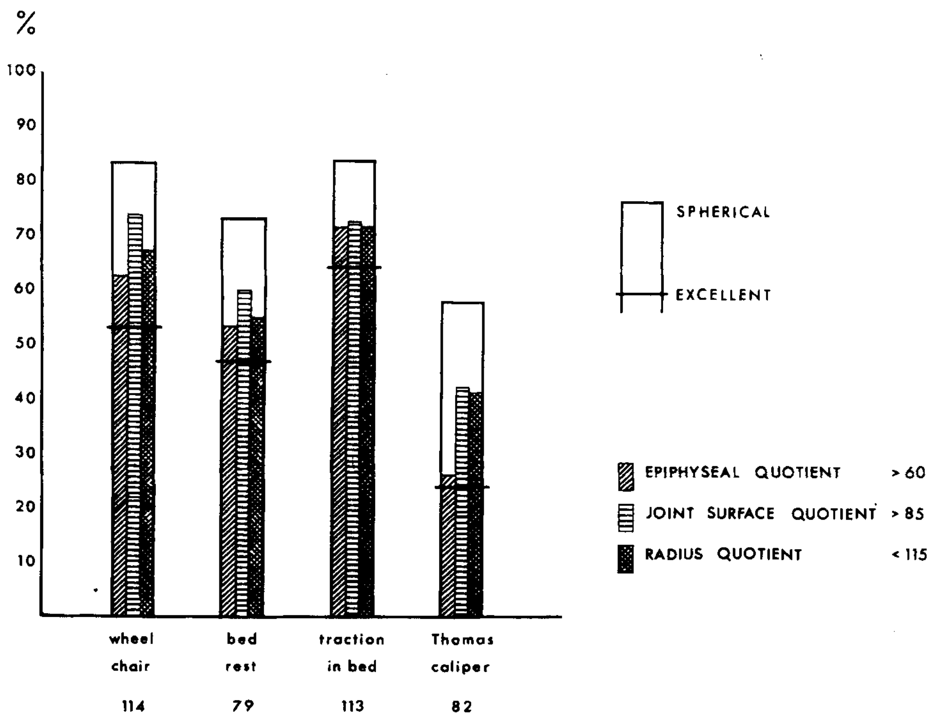

Fig. 26: Influence of method of non-weightbearing on attaining sphericity and good quotients in all 388 unilateral cases.
Wheel chair: 64% excellent and 36% good of the 94 spherical
Bed rest: 65% excellent and 35% good of the 57 spherical
Traction in bed: 77% excellent and 23% good of the 94 spherical
Thomas caliper: 43% excellent and 57% good of the 47 spherical

Statistical assessment concerning shape and distribution of quotient:

Spherical-Fair-Poor: $X^2 = 34.29$ df = 6 $P < 0.001$ (high significance)

Excellent-Good: $X^2 = 16.91$ df = 3 $P < 0.001$ (high significance).

Summing up, it may be assumed that the youngest cases and those of the mildest course have a chance of attaining sphericity, even without a sufficiently long protection from weightbearing.

Even after a somewhat longer-lasting protection from weightbearing by bed rest, but not beyond 1 year, Hauge (1957) found spherical heads in only 32.6% of 100 patients. Taussig & Héripret (1969), like Helbo, found 80% spherical among 187 treated with long-term bed rest. Katz (1967) also found 80% spherical among his 235 patients treated with bed rest + traction or + abduction brace. Mose (1964) had 45% good results (sphericity + EpQ over 60) among his 71 patients treated with Thomas caliper and 59.5% among his 148 patients treated with bed rest.

Among 45 patients treated with non-weightbearing for an average of 3 years, the last 2 years by a Thomas caliper, Ebach (1968) found sphericity in 60%, EpQ above 60 in 47%, and JsQ above 85 in 51%. Sanders & MacEwen (1969) had 60.1% with a radius variation up to 2 mm among 126 rapidly healed patients receiving early ambulatory treatment with Snyder's sling. Meyer's analysis (1966) of the first 71 cases treated with traction in bed at the Seaside Hospital, Refsnæs, corresponds surprisingly to the present results for twice the number of patients, in percentage of sphericity as well as the various quotients.

On the other hand, it is more difficult to make any comparison with Steinhauser's results (1970), as he stated his quotient results for spherical and irregular heads together. Unlike the general tendency in my findings, he had a higher percentage having an EpQ exceeding 60 than having a JsQ exceeding 85.

However, any comparison of different materials is not of much value, unless regard is paid to the composition of the materials. In the attempt to attain comparability between two groups of patients treated by different methods, Pedersen & McCarroll (1951) selected from their total material 12 patients who had been treated with traction in bed and 12 treated as out-patients with crutches and non-weightbearing. Both groups were of the same stage distribution. By far the best results were found after traction in bed. Evans & Lloyd-Roberts (1958) also selected two groups of 12 patients each, paying regard to sex, age, and stage. They found that those treated as out-patients with Snyder's sling obtained equally good results as those treated with traction in bed in hospital.

Störig (1968), selecting patients comparable in stage and age, found that the 15 treated by operation had attained somewhat better results than the 15 treated conservatively in plaster.

COMPARABILITY OF THE THERAPEUTIC METHODS:

The four series of the present material were in fact treated according to the same principle, viz. with protection of the affected leg from weightbearing for a long time. Only the manner of this protection differed.

Out-patient treatment and in-patient treatment are very different, financially as well as socially and familially, when the period of treatment is as long as is necessary in LCPD. It is of great importance, therefore, to ascertain the real value of each method when paying regard to the comparability of the materials.

Period of Non-weightbearing.

In the various parts of the world it has been most common for each treatment centre to use a standardized treatment for all patients with LCPD during a given period of time. However, Weigert (1968) has suggested individualizing the treatment according to stage.

The present 4 series too are based upon the principle of a given treatment for all patients as soon as the diagnosis has been made.

The radiological course was followed at a few months' intervals. The children were allowed weightbearing when the healing was so far advanced that major defects had been filled and the epiphyseal surface contours were again fairly continuous. Thus, the time of weightbearing was decided according to the subjective estimate of the various doctors who followed the patients. Bagliani & Canale (1968) used arthrography for assessing when the cartilage-covered head could again bear weight.

Table 38: Average period of non-weightbearing in 388 unilateral cases:

Wheelchair series	114	22.8 months
Bed rest series	79	24.6 months
Traction in bed series	113	22.0 months
Thomas caliper series	82	19.9 months

Table 38 shows that the period of non-weightbearing was of approximately the same length in the four series, but of course it must be borne in mind that the Thomas caliper series had been protected from weightbearing for a few months less than the other series.

The wheelchair treatment was predominantly on an out-patient basis, although 12 patients had been in an institution during the entire treatment period and a few during short parts of it. It has been mentioned already that this treatment had not been carried through with equal consistency in the out-patients, so that this series may be divided into 3 qualities of non-weightbearing.

I did not investigate how the Thomas caliper treatment had been carried through, but I assume that the attitude to supervising the therapeutic principle has been approximately the same among the parents of these children as among those of the wheelchair patients. Therefore, the two ambulatory series ought to be comparable as a whole, as the results in the wheelchair group are altered by less than 1%, if the 12 institutionalized patients are excluded.

Within the bed rest series a large number of the patients had been treated during part of the non-weightbearing period as ambulatory cases with Snyder's sling. This applies especially to the first years. However, the mean stay in the Seaside Hospital was 22.1 months, corresponding quite accurately to the treatment period in the traction in bed series in which most patients had been in hospital throughout the non-weightbearing period. To make children understand why they are to lie in bed for 12 - 18 months, when otherwise they are feeling perfectly fit, is of course difficult, even in hospital. The traction treatment at the Seaside Hospital was introduced to secure better immobilization and non-weightbearing during the first year of treatment. However, the entire traction in bed series did not receive exactly the same treatment. Thus, 18 patients were not treated with traction at all. Two had been treated with traction for less than 6 months and 4 for 7 - 10 months. The motivation for lacking traction is apparent from the patient list. 10 of the 18 patients not treated with traction were under 5 years of age and/or had only dysplasia. The other unilateral cases were treated periodically with a 1 - 1½ kg traction on both legs, in a slightly bent and abducted position, for 11 - 14 months, mean 12 months. If those not treated with traction are excluded, the result in the remaining 95 patients of the traction in bed series is only slightly worse. It was, therefore, considered reasonable to consider the entire series as having received the same treatment. The bed rest series and the traction in bed series must be comparable with other forms of observed non-weightbearing treatment.

Follow-up Period.

As already mentioned, there was a slight difference in the follow-up periods. Since the present analysis was performed, Meyer has systematically followed the entire traction in bed series an average of 2 years later. He found that the results had improved only very slightly. Especially the radius quotients were somewhat better, but the percentage of spherical heads had not changed, and the other quotients only very slightly. The small difference in the follow-up period, therefore, is of little consequence to the comparability.

Sex Ratio.

As the boys-girls ratio is approximately the same in all 4 series, and as the sex factor has no influence upon the attainment of sphericity, no regard will be paid to the sex ratio in the comparison.

Age Distribution.

The age factor is of the utmost importance to the result, and accordingly regard must be paid to the essential difference in age distribution between the series. The results of the 4 treatments in the three age groups are shown in Table 39, to be compared with figs. 27, 28, and 29.

When considering the reduced number of patients in the subgroups, the values nevertheless seem to confirm the previously advanced claim that age is an important factor in attaining a good final shape. The degree of non-weightbearing apparently plays rather less role in attaining a spherical head. This is most distinctly manifest by the fairly large number of spherical heads in the youngest Thomas caliper group. In return, the quality of non-weightbearing seems to have an essential influence upon how close the healing of the head approaches normal appearance, in terms of the quotients. In this respect the traction in bed series is distinguished by a very large number of excellent results among the spherical heads. The apparently high percentage of sphericity in the 8 oldest patients of the wheelchair series cannot be attributed with any importance owing to the small numbers involved. It is only in the age group 5 - 8 years that the treatment has had a real influence upon the shape as well as the quotients (legend to Fig. 28).

Table 39: Results in the three age groups of the 4 series:

		Excellent	Good	Fair	Poor
< 5 years					
Wheelchair	37	24 (65%)	9 (25%)	2 (5%)	2 (5%)
Bed rest	17	12 (71%)	5 (29%)	0 (0%)	0 (0%)
Traction in bed	31	25 (81%)	5 (16%)	0 (0%)	1 (3%)
Thomas caliper	19	8 (42%)	7 (37%)	3 (16%)	1 (5%)
< 5 years	104	69 (66.4%)	26 (25.0%)	5 (4.8%)	4 (3.8%)
5-8 years					
Wheelchair	69	35 (51%)	21 (30%)	9 (13%)	4 (6%)
Bed rest	48	20 (42%)	13 (27%)	7 (14%)	8 (17%)
Traction in bed	62	41 (66%)	16 (26%)	2 (3%)	3 (5%)
Thomas caliper	53	12 (23%)	19 (36%)	3 (5%)	19 (36%)
5-8 years	232	108 (46.5%)	69 (29.8%)	21 (9.0%)	34 (14.7%)
> 8 years					
Wheelchair	8	1 (13%)	4 (50%)	2 (25%)	1 (12%)
Bed rest	14	5 (36%)	2 (14%)	3 (21%)	4 (29%)
Traction in bed	20	6 (30%)	1 (5%)	6 (30%)	7 (35%)
Thomas caliper	10	0 (0%)	1 (10%)	3 (30%)	6 (60%)
> 8 years	52	12 (23.1%)	8 (15.4%)	14 (26.9%)	18 (34.6%)

< 5 YEARS:

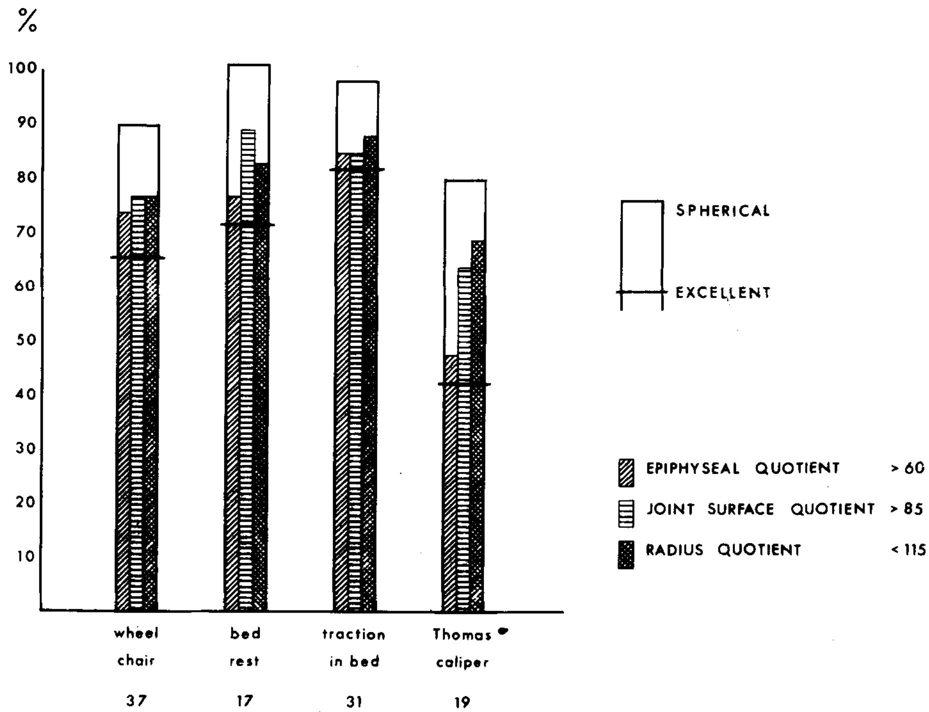

Fig. 27: Influence of method of non-weightbearing upon the attainment of sphericity and good quotients in the 104 unilateral cases under 5 years of age.

Wheelchair: 73% excellent and 27% good of the 33 spherical
Bed rest: 71% excellent and 29% good of the 17 spherical
Traction in bed: 83% excellent and 17% good of the 30 spherical
Thomas caliper: 53% excellent and 47% good of the 15 spherical

Statistical assessment of shape and quotients:

Spherical-Fair-Poor: $X^2 = 8.70$ df = 6 $0.1 < P < 0.2$ (no significance)
Excellent-Good: $X^2 = 4.57$ df = 3 $P = 0.2$ (no significance)

5 - 8 YEARS:

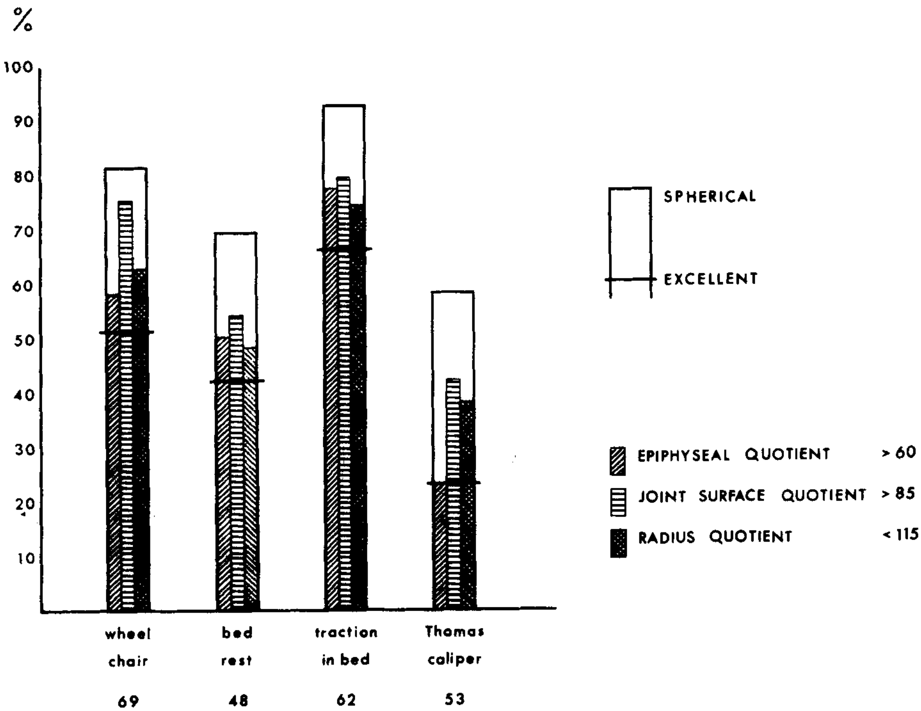

Fig. 28: Influence of method of non-weightbearing upon the attainment of sphericity and good quotients in the 232 unilateral cases between 5 and 8 years of age.

Wheelchair: 62% excellent and 38% good of the 56 spherical
Bed rest: 61% excellent and 39% good of the 33 spherical
Traction in bed: 72% excellent and 28% good of the 57·spherical
Thomas caliper: 39% excellent and 61% good of the 31 spherical

Statistical assessment of shape and quotients:

Spherical-Fair-Poor: $X^2 = 32.70$ df = 6 $P < 0.001$ (high significance)
Excellent-Good: $X^2 = 11.83$ df = 3 $P < 0.01$ (significant)

> 8 YEARS:

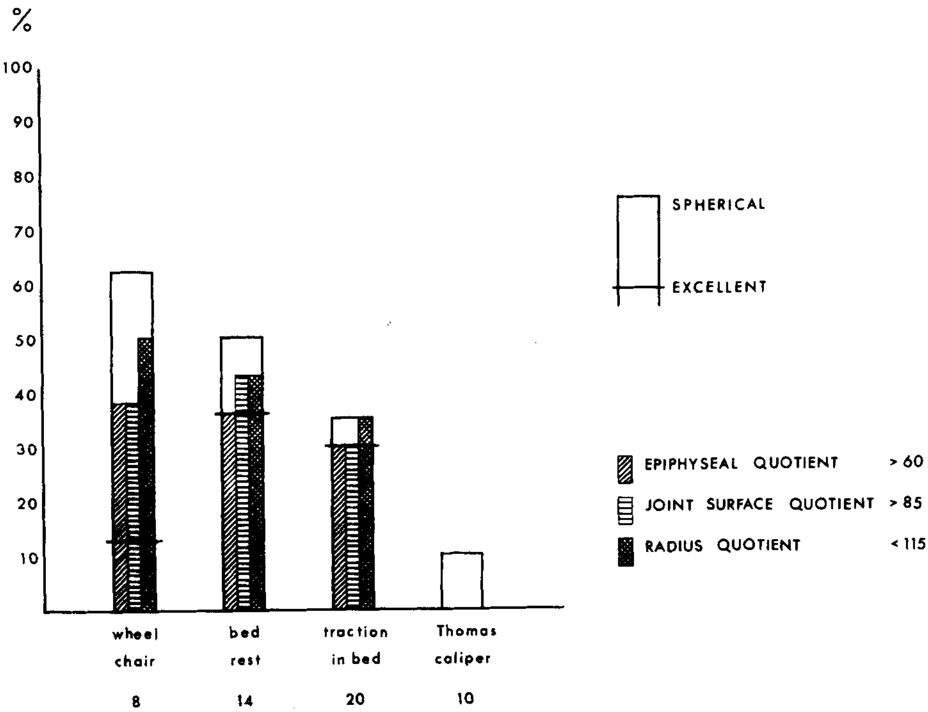

Fig. 29: Influence of method of non-weightbearing upon the attainment of sphericity and good quotients in the 52 unilateral cases over 8 years of age.

Wheelchair:	20% excellent and 80% good	of the 5 spherical
Bed rest:	71% excellent and 29% good	of the 7 spherical
Traction in bed:	86% excellent and 14% good	of the 7 spherical
Thomas caliper:	0% excellent and 100% good	of the 1 spherical

Statistical assessment of shape and quotients:

Spherical-Fair-Poor: $X^2 = 7.27$ df = 6 P = 0.3 (no significance)
Excellent-Good: $X^2 = 7.14$ df = 3 $0.05 < P < 0.1$ (no significance).

Stage and Degree Distribution.

The degree depends highly upon the stage. However, the method of non-weightbearing has a marked influence upon this relationship, as the most effective protection from weightbearing will best prevent a severe degree in those who arrive late for treatment and the least effective protection will most often cause a severe degree in those receiving early treatment (Tables 35 and 36). Although the degree is a factor of the utmost prognostic importance and is not solely dependent upon the stage and non-weightbearing factor, it is difficult to include in the analysis.

What is of interest is an assessment of each patient's prognosis on the basis of factors known when the disease is diagnosed, so that it can be decided which protection from weightbearing is needed. At the time of diagnosis, the age is known and the initial quotient may be measured on the primary X-ray films.

In the further comparison of the series, therefore, regard will be paid to age and stage, and a combination of these two factors seems most relevant.

The result, calculated in per cent of spherical and excellent, is given in Table 40. Here the numerical groups have become so small that the calculation of percentage can only be accepted with marked reserve.

The Thomas caliper treatment is lowest in all sub-groups. In the > 8-years group far less than half attain sphericity, and less than one-quarter become excellent. As compared with the influence of age, the influence of stage and quality of non-weightbearing is reduced in importance. Note should be taken especially of the extremely poor results among the patients treated with Thomas caliper.

In the youngest group there is a very high percentage of spherical heads in all sub-groups. The moderate influence of stage as well as of non-weightbearing efficiency is seen in the number of excellent results, but also in the number of spherical heads.

In the middle age group, numerically the largest and therefore the most important to know about, the tendencies from the youngest groups are more distinct.

When the values are presented graphically (Fig. 30), it may be seen that the more effective the protection from weightbearing, the higher the percentage of sphericity. At the same time, the influence of the stage is reduced (spread of solid lines). This reflects the significance of the various non-weightbearing methods to the degree in relation to the stage (cf. Tables 35 and 36). On the other hand, the method of non-weightbearing does not appear to mean nearly as much to the influence of stage upon the quotients and thereby upon the percentage obtaining excellent results (spread of broken lines).

Table 40: Distribution of results in the 4 series, paying regard to age and stage:

388 patients			114 Wheel chair		79 Bed rest		113 Traction in bed		82 Thomas caliper	
< 5 years &										
IQ > 85:	39		20		1		10		8	
Spherical	35	(90%)	18	(90%)	1	(100%)	10	(100%)	6	(75%)
Excellent	29	(74%)	15	(75%)	1	(100%)	10	(100%)	3	(38%)
< 5 years &										
IQ ≤ 85:	65		17		16		21		11	
Spherical	60	(92%)	15	(88%)	16	(100%)	20	(95%)	9	(82%)
Excellent	40	(62%)	9	(53%)	11	(69%)	15	(71%)	5	(45%)
5 - 8 years &										
IQ > 85:	98		42		17		23		16	
Spherical	84	(86%)	36	(86%)	13	(77%)	22	(96%)	13	(81%)
Excellent	66	(67%)	28	(67%)	11	(65%)	21	(91%)	6	(38%)
5 - 8 years &										
IQ ≤ 85:	134		27		31		39		37	
Spherical	93	(69%)	20	(74%)	20	(65%)	35	(90%)	18	(49%)
Excellent	42	(31%)	7	(26%)	9	(29%)	20	(51%)	6	(16%)
> 8 years &										
IQ > 85:	27		6		7		12		2	
Spherical	11	(41%)	4	(67%)	4	(57%)	3	(25%)	0	(0%)
Excellent	6	(22%)	1	(17%)	2	(29%)	3	(25%)	0	(0%)
> 8 years &										
IQ ≤ 85:	25		2		7		8		8	
Spherical	9	(36%)	1	(50%)	3	(43%)	4	(50%)	1	(13%)
Excellent	6	(24%)	0	(0%)	3	(43%)	3	(38%)	0	(0%)

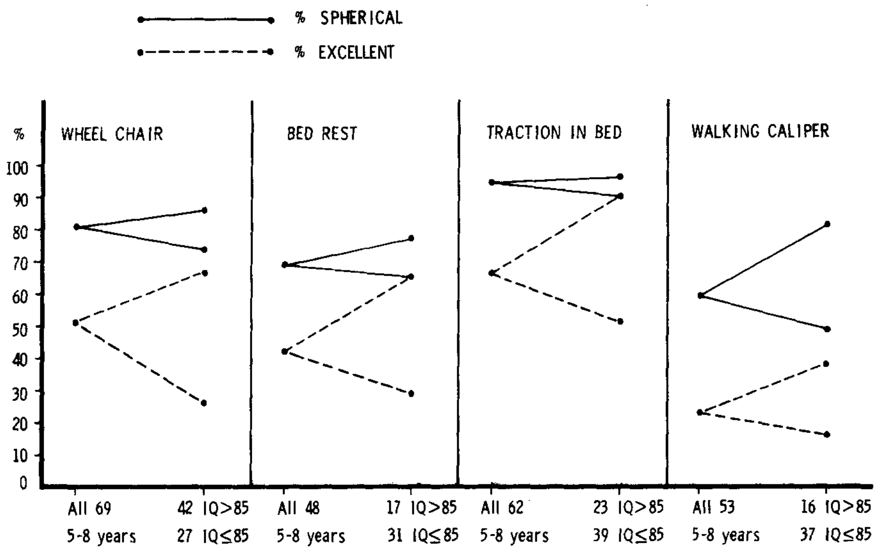

Fig. 30: Influence of stage upon obtaining sphericity and good quotients in the 5 - 8-year-olds by the 4 methods of non-weightbearing.

EFFICACY OF THE WHEELCHAIR METHOD AS COMPARED WITH THE OTHERS:

When a doctor is to take the responsibility for the treatment of a disease, it is necessary, of course, that the treatment is observed as prescribed. This also applies to the treatment of LCPD by non-weightbearing. It is not acceptable that every fifth patient is inadequately treated, if this gives a poorer result. Therefore, I analysed the result in the 3 groups of differently observed wheelchair treatment. When the 12 institutionalized patients are assigned to the group of perfectly protected from weightbearing, the 112 recorded wheelchair cases are distributed as follows:

33 perfectly protected from weightbearing	(29%)
60 well protected from weightbearing	(54%)
19 badly protected from weightbearing	(17%)

The distribution by sex, age, duration of symptoms, IQ, degree, and duration of disease in these 3 groups is apparent from Table 41.

Table 41: Distribution of the various factors in the three groups treated in wheelchair:

112 patients		Protected from weightbearing: Perfectly 33 (29%)	Well 60 (54%)	Badly 19 (17%)
Sex:				
Boys	92 (82%)	28 (85%)	47 (78%)	17 (89%)
Girls	20 (18%)	5 (15%)	13 (22%)	2 (11%)
Age:				
< 5 yrs.	37 (33%)	11 (33%)	19 (32%)	7 (37%)
5 - 8 yrs.	69 (62%)	20 (61%)	38 (63%)	11 (58%)
> 8 yrs.	6 (5%)	2 (6%)	3 (5%)	1 (5%)
Duration of symptoms:				
0 - 3 months	78 (70%)	23 (70%)	44 (74%)	11 (58%)
4 - 6 months	25 (22%)	9 (27%)	11 (18%)	5 (26%)
> 6 months	9 (8%)	1 (3%)	5 (8%)	3 (16%)
Stage:				
IQ > 85	67 (60%)	21 (64%)	37 (62%)	9 (47%)
IQ ≤ 85	45 (40%)	12 (36%)	23 (38%)	10 (53%)
Degree:				
Mild	57 (51%)	19 (58%)	33 (55%)	5 (26%)
Severe	55 (49%)	14 (42%)	27 (45%)	14 (74%)
Duration of disease:				
< 4 yrs.	50 (45%)	22 (67%)	23 (38%)	5 (26%)
4 - 6 yrs.	45 (40%)	9 (27%)	28 (47%)	8 (42%)
> 6 yrs.	17 (15%)	2 (6%)	6 (15%)	6 (32%)

There is no difference in the sex ratio or age distribution between the three groups. On the other hand, there is among the badly protected cases a certain excess frequency of longest duration of symptoms and IQ below 85 as well as a corresponding increase of severe degree and thereby also of the longest average duration of the disease.

The stage distribution will of course entail a relatively poorer result among the badly protected cases, whereas the result in the groups perfectly and well protected is not influenced by age or stage

Table 42: Result in the three wheelchair groups:

112 patients		Protected from weightbearing: Perfectly 33	Well 60	Badly 19
Excellent	60	20 (61%)	36 (60%)	4 (21%)
Good	34	10 (30%)	18 (30%)	6 (32%)
Fair	12	2 (6%)	5 (8%)	5 (26%)
Poor	6	1 (3%)	1 (2%)	4 (21%)

to be compared with Fig. 31.

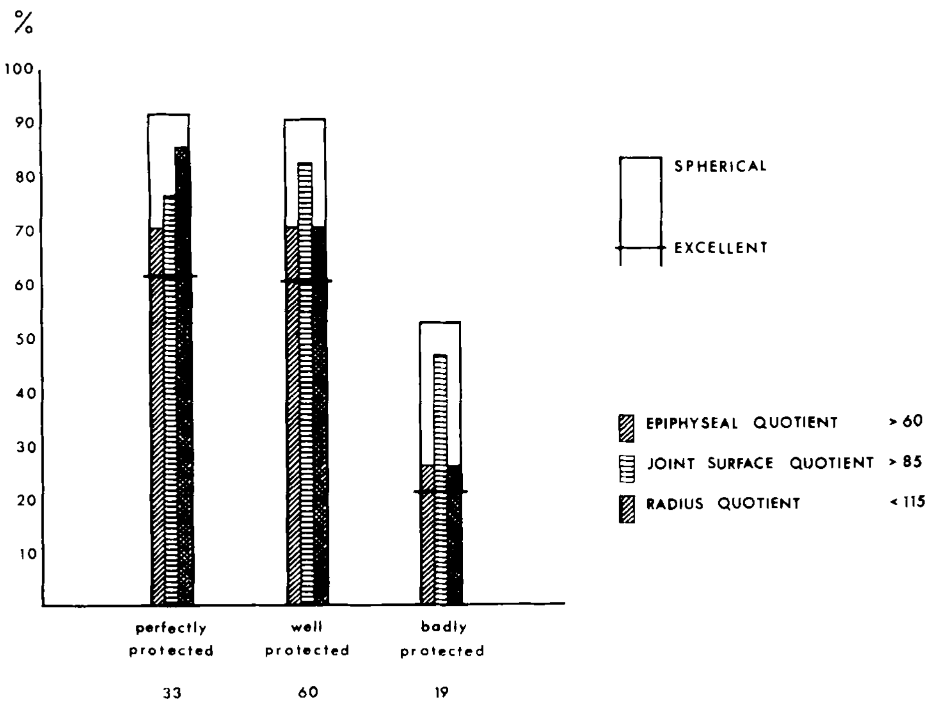

Fig. 31: Importance of observing non-weightbearing in wheelchair to obtaining sphericity and good quotients:

Perfectly: 67% excellent and 33% good of the 30 spherical
Well: 67% excellent and 33% good of the 54 spherical
Badly: 40% excellent and 60% good of the 10 spherical

Table 42, to be compared with Fig. 31, shows surprisingly that the groups perfectly and well protected from weightbearing have obtained exactly the same results, whereas the group of badly protected patients has, as might be expected, obtained a considerably lower percentage of spherical and excellent. If these values are compared with Fig. 26, it will be seen that the group of badly protected from weightbearing in a wheelchair achieves a result very similar to that of treatment with Thomas caliper, whereas in the perfectly and well protected wheelchair patients the results are almost on a level with those in the traction in bed series. Again, we must remember that these groups are not entirely comparable, as the wheelchair series has the advantage of an earlier age and an earlier stage. However, it is not possible to make further comparisons, as this would make the sub-groups too small, with respect to age as well as stage.

CONCLUSIONS CONCERNING TREATMENT WITH NON-WEIGHTBEARING:

Previous investigations have shown that no or short-lasting non-weightbearing affords in general a considerably lower percentage than long-lasting non-weightbearing of femoral heads healing in spherical shape.

When deciding which method to use for long-lasting protection from weightbearing in patients with LCPD, the personal and social disadvantages of the methods, and possibly their cost, have to be weighed against the chance they afford of leading to the best prognostic result.

Very prolonged bed rest in hospital with traction on both legs is the most effective form of non-weightbearing and will thereby in general afford the best healing results. When out-patient treatment sitting in a wheelchair is correctly observed, it is at least as effective, from the point of view of non-weightbearing, as long-lasting bed rest in hospital without traction, and nearly as effective as traction in bed. Ambulatory treatment with a Thomas caliper is considerably less effective, giving results on a level with those of badly observed wheelchair treatment.

However, the other prognostic factors exert such a marked influence that regard must be paid also to them.

The age factor plays an enormous role in the shape of healing.

The younger the children at the onset of the disease, the better the prognosis.

Under the age of 5 years the prognosis is in general very good, even where the treatment is started at a late stage. In such young children, however, it has proved more difficult to carry through an ambulatory protection from weightbearing than during admission to hospital. Protection by a Thomas caliper is most insufficient at this age, whereas wheelchair treatment gives slightly poorer results than treatment in hospital. Traction does not increase the effect of the bed rest in hospital.

In the age group 5 - 8 years, by far the most common for the onset of the disease, it is important that the diagnosis be made as early as at all possible. If non-weightbearing is started before epiphyseal flattening has taken place, the ambulatory methods can afford an equally high percentage of sphericity as bed rest in hospital and only slightly poorer than bed rest with traction. The method of non-weightbearing, however, is of rather essential importance to the way in which the femoral head regenerates, and in this respect again the Thomas caliper treatment will prove inferior to the other methods. If non-weightbearing is not started until a late stage, at which the epiphysis has already flattened, there is more likelihood of a severe degree of epiphyseal changes, a long duration, and a higher percentage of healing in an irregular shape than if non-weightbearing is started early. In such cases it is of particular importance to protect as effectively as possible from weightbearing. A Thomas caliper will be absolutely inadequate, and only bed rest with traction in hospital can give the very best results.

When the disease occurs in children over 8 years of age the prognosis is much poorer, but as in the youngest group less dependent on the stage. Again, the Thomas caliper proves inadequate, whereas treatment in a wheelchair protects the children as well as does treatment in hospital. Even long-lasting traction in hospital cannot give a higher percentage of healing in spherical shape.

The prognosis of the special type of course called dysplasia epiphysialis capitis femoris is so favourable that the method of non-weightbearing plays no role.

CHAPTER 12

BILATERAL CASES

DISTRIBUTION, RELATIONS, AND RESULT:

The three consecutive series include a total of 58 patients with LCPD changes in both hips. Out of these 116 hips, however, only 109 can be considered as treated, as 3 had been untreated, 3 had been treated previously and 1 later than the periods stated for these series. The bilateral cases were recorded by sex, age at institution of treatment, subjective assessment of radiological stage, and degree of epiphyseal changes during the course as well as the healing result according to measurements with the template.

Tables 10 and 43 show that the sex distribution was approximately the same in the unilateral and bilateral cases. From Tables 11 and 44 as well as Figs. 18 and 32 it is apparent that the age summit in the bilateral cases is 2 - 3 years earlier than in the unilateral ones. This gives a mean age of 5.2 years in the bilateral cases as compared with 6.0 years in the unilateral ones. This age difference is in agreement with the findings of Broder (1958) and Mose (1964).

Table 43. Sex ratio:

	Wheelchair	Bed rest	Traction in bed
58 patients	21	13	24
50 boys (86%)	18	11	21
8 girls (14%)	3	2	3

Results:

In analysing the end result I went by the same criteria for the time of measurement as in the unilateral cases. All hips were assessed by the template measurement. In the wheelchair series, moreover, epiphyseal height and width were measured as well as the height of the femoral head, so that the epiphyseal index (EpI) and

Table 44. Age distribution:

Years	Patients	Per cent
2	5	4.6
3	23	21.1
4	23	21.1
5	20	18.4
6	10	9.2
7	8	7.3
8	7	6.4
9	7	6.4
10	3	2.8
11	2	1.8
12	1	0.9

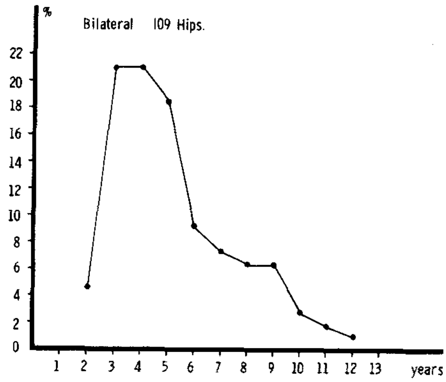

Fig. 32: Age distribution of the bilateral cases.

joint surface index (JsI) could be calculated. On the basis of an EpI value of 60% and a JsI value of 85% of those in the normal range, paying due regard to the age difference, it was attempted to distinguish an excellent group among the cases with spherical heads. This revealed 19 excellent results out of 31 spherical among the 39 patients treated in wheelchair. Applying the values reported by Mose (1964) for the EpI in the bed rest series, I found that 11 of the 20 spherical cases had an EpI above 60.

Table 45. Result of treating the bilateral cases:

	Hips	Spherical heads	Excellent
Wheelchair series	39	31 (80%)	19 (49%)
Bed rest series	25	20 (80%)	11 (44%)
Traction in bed series	45	41 (91%)	
Total bilateral cases	109	92 (84%)	

From table 45 it is apparent that the result in the bilateral cases has been, on the average, slightly better than among the unilateral cases. This must be ascribed to an earlier age and a relatively larger number with d.e.c.f., especially among the youngest patients.

Table 46. Result by age, degree, and stage groups.

			Wheelchair		Bed rest		Tr. in bed	
	Number	Spherical	No.	Spher.	No.	Spher.	No.	Spher.
Age	109	92 (84%)	39	31	25	20	45	41
< 5 yrs.	51	48 (94%)	17	16	12	11	22	21
5 - 8 yrs.	45	39 (87%)	19	15	8	8	18	16
> 8 yrs.	13	5 (39%)	3	0	5	1	5	4
Degree	100	83 (83%)	36	28	22	17	42	38
D.e.c.f.	30	30 (100%)	9	9	4	4	17	17
Mild	20	19 (95%)	10	9	4	4	6	6
	50	34 (68%)	17	10	14	9	19	15
Stage	79	62 (78%)	30	22	21	16	28	24
No flattening	18	16 (89%)	8	6	6	6	4	4
Flattening	19	12 (63%)	6	4	5	3	8	5
Fragmentation	33	25 (76%)	13	9	7	4	13	12
Healing	9	9 (100%)	3	3	3	3	3	3

From Table 46 it is evident that the dependence of the results upon age is exactly as in the unilateral cases (cf. Table 31). Cases of the d.e.c.f. type obtain 100% good results, also when bilateral. Out of the 30 d.e.c.f. cases 10 patients had these changes in both hips and 10 only on one side. 20 of the d.e.c.f. hips were in patients under 5 years of age, viz. 7 bilateral and 6 unilateral. The difference in the result between mild and severe degrees of changes corresponds to that in the unilateral cases (cf. Table 33).

Owing to the large number of d.e.c.f. cases, I sorted them off in assessing the stage at institution of treatment. The result in the remaining 79 hips, related to subjective assessment of stage, is also shown in Table 46.

Each treatment group is very small, but when they are added up it may be seen, as in the unilateral cases, that the chances of a good result are much greater if treatment is started before epiphyseal flattening has taken place.

Strangely enough all 9 hips which had reached the stage of healing before non-weightbearing treatment was started attained spherical heads, and so did three-quarters of the fragmented cases. This is to some extent explained by the early age at onset of the disease in most of the cases. For the sake of completeness, it may be mentioned that of the 7 excluded hips not treated within these series only 3 had attained sphericity.

Six of the 21 patients of the wheelchair series had developed the disease in the second hip while they were being treated with a Thomas caliper for the 1st hip. The others were bilateral at the time of diagnosis. No patient developed changes on the previously healthy side while being treated in a wheelchair.

CONCLUSION:

In the group of 58 patients with changes of both hips quite a large number had the special type called dysplasia epiphysialis capitis femoris (d.e.c.f.), viz. very mild radiological changes without actual condensation or collapse of the epiphysis. Often these cases occur at the age of 3 or 4 years and contribute to lowering the mean age and improving the results, as all healed in spherical shape during the treatment. The fact that 10 patients had d.e.c.f. of one hip and true LCPD of the other indicates a relationship, and presumably there is a certain risk that a case of d.e.c.f. may progress into LCPD, if not protected from weightbearing.

Among the bilateral cases too out-patient treatment in a wheelchair afforded good results approximately up to those obtained by treatment in hospital. As in the unilateral cases, the result depended upon stage, age, type, and quality of protection from weightbearing.

Out of the 21 bilateral cases of the wheelchair series none had developed the disease in the other hip while being protected from weightbearing in a wheelchair for disease of one hip, whereas this occurred in 4 cases being treated primarily with a Thomas caliper.

CHAPTER 13

SUMMARY AND CONCLUSIONS

SUMMARY OF THE CHAPTERS:

Chapter 1 relates the discovery of the disease and the most important traits of its early history, its incidence of about one in a thousand of the white race, and its clinical features. The characteristic radiological course is described, and it is emphasized that a condensed, flattened epiphysis is a late stage of the disease, even in the absence of fragmentation. Laboratory tests show no definite characteristics.

Chapter 2. After a description of the most important topography of the hip joint, a more detailed account is given of the arterial supply of the femoral head in children, illustrated int. al. by the present author's injection experiments using Spalteholz preparation on child cadavers. Lastly, the innervation of the hip joint is described.

Chapter 3 recounts the pathological findings in and around the femoral head in LCPD, int. al. on the basis of the author's study of two autopsy specimens. The findings are compared with similar pathology in various animal species and with the numerous experimentally induced epiphyseal necroses in animal experiments.

Chapter 4 gives the known relationships to other diseases. Congenital dislocation of the hip, especially when receiving late treatment, leaves epiphyseal changes in som cases. The possible relationship to transient synovitis of the hip is mentioned. It seems beyond doubt that LCPD often affects children with delayed skeletal maturation, whereas the various enchondral dysostoses appear to run a course different from LCPD. After a comparison with the various non-traumatic and traumatic epiphyseal necroses, the author advances an aetiological theory based upon partial or intermittent compression of the most important artery to the epiphysis.

Chapter 5 reports, on the basis of the literature, the numerous ways of protecting children with LCPD from weightbearing. Attempts at supplementary treatment are mentioned. Lastly, the author deals with the various operative treatments, partly the drillings and nailings used previously, partly the more recent, increasing use of corrective varisation derotation osteotomy the results of which are not yet quite clear.

Chapter 6 reviews the long-term folow-up studies of LCPD published so far. With follow-up periods of up to 40 years, they demonstrate that femoral heads healing in spherical shape do not develop osteoarthritis, whereas this occurs with increasing frequency the more irregular the shape of the head. It is the general impression that the patients do much better subjectively than the X-ray appearances would lead one to believe.

Chapter 7 presents the author's material which comprises 475 patients, 29 of whom were excluded. The origin of the 4 series is defined. The investigations are based on the 388 unilateral cases, primarily upon the 114 patients treated in their homes sitting in a wheelchair and compared with 79 patients treated with bed rest in hospital, 113 treated with bed rest + intermittent traction in hospital, and 82 treated as out-patients with the Thomas caliper.

After a description of the wheelchair regimen, an account is given of how it was in fact practised, on the basis of a follow-up study. One-fifth had strictly observed the regimen, three-fifths had administered it less strictly, but without bearing weight, whereas one-fifth had been unable to cope with it. This different administration of the regimen was analysed in relation to the familial, social, and housing conditions, but no definite relationship was found. The tendency to a familial accumulation of the disease is substantiated by 16 known cases among the 135 wheelchair patients. Finally, the clinical symptoms and findings in the wheelchair series are mentioned.

Chapter 8. After evaluating previous measuring methods for assessing the healing result, the author states the criteria and basis of the measuring methods used for assessing the present material. Primarily, the shape of the healed head was assessed by a template and divided into spherical, with a radius variation of less than 2 mm, irregular with a radius variation of 2 - 4 mm, and very irregular above 4 mm. The spherical femoral heads were assessed on the basis of an epiphyseal quotient, a joint surface quotient, and a radius quotient, designating the optimally healed ones as excellent. The limits were based on measurements of a normal material.

The value of the measuring methods was adjudged by measuring on X-ray films in both views and calculating the means. The importance of the measuring accuracy was analysed, and an accuracy of 1 mm was found applicable. Three of the series have been measured also by another investigator, and the difference between the two sets of values in all the methods used corresponds to a measuring accuracy of 1 mm. This is taken to prove the applicability of the method in a comparative study, with a suitably narrow margin of error.

Chapter 9 deals with first the sex, side, and age distribution of the 388 unilateral cases, which showed no interrelationship. For practical reasons, the material was divided, in the further analysis, into 3 age groups, under 5 years, 5 - 8 years, and over 8 years at institution of treatment. On the basis of the X-ray films at institution of treatment, subjective staging was related to a measurement of initial epiphyseal flattening. An initial quotient of 85 was found to be a fitting objective limit between an early and a late stage. A relationship was detected between this staging and data concerning the duration of symptoms, which had also been somewhat longer in the oldest age group. The 4 basic series differed somewhat in the distribution of the stage and age groups.

The degree of fragmentation in the epiphysis was evaluated, and dysplasia epiphysialis capitis femoris (d.e.c.f.) was distinguished as a special type. The oldest age group had most often a mild degree. Besides, a marked, but not consistent relationship was found between a late stage and a severe degree. There was also a distinct relationship between a severe degree and the total duration of the disease processes as well as the period of non-weightbearing needed.

<u>Chapter 10</u> analyses the influence of sex, age, stage, and degree upon the healing shape and quotient values. Girls obtained poorer quotients, whereas sex had no influence upon the shape of healing. Age has a highly decisive influence upon the shape of healing, there being by far the largest number of spherical shapes in the youngest and by far the largest number of irregular shapes in the oldest age group. The quotient values are age-dependent parallel to the dependence of the shape. The partial interrelationship of stage and degree required a combined analysis of these parameters. It showed that the severe degree results in most bad shapes, whereas stage has more influence upon the quotient values. The influence of the therapeutic method upon the relationship between stage and degree was assessed, showing that traction in bed better than the others prevents a severe degree in cases of a late stage. The d.e.c.f. cases always give very fine healing results.

<u>Chapter 11</u> deals with the role of treatment, assessing the protective effect of each therapeutic method. Owing to differences in age and stage between the 4 series, certain corrections have to be made before comparing the results. When this has been taken into consideration, the analysis showed that out-patient treatment in wheelchair is as effective as bed rest in hospital. Traction in bed proved most effective and Thomas caliper least effective. In that part of the wheelchair series in which the regimen could not be carried through (one-fifth), the result is on a level with that with Thomas caliper. Wheelchair treatment carried through without the patients bearing weight is from the protective point of view an absolutely justifiable alternative to treatment in hospital, in particular if the treatment is instituted at an early stage.

<u>Chapter 12</u> is devoted to the 58 bilateral cases whose age summit is somewhat lower than that of the unilateral cases, but there is no difference in sex ratio. The d.e.c.f. type is somewhat more common, among the bilateral cases, and when considering also the earlier age, we presumably have the explanation of the slightly better results than in the unilateral cases as regards the percentage healing in spherical shape. No patient of the wheelchair series had developed the disease in the contralateral hip while being treated in the wheelchair.

GENERAL CONSLUSION:

The study confirmed that LCPD is a disease which arises by far most commonly in boys aged 5 - 7 years and which shows a definite familial tendency. It affects the epiphysis of the femoral head which undergoes necrotic changes involving the bone marrow and bony tissue, but not the articular cartilage or epiphyseal plate. Most probably, the necrosis is due to relative or intermittent ischaemia of the epiphysis due to local vascular changes depending on age, race, and possibly also on sex and heredity. The condition is bilateral in roughly 10%, and in that case occurs at an earlier average age than when unilateral.

Its symptoms are a limp and periodical pain in the hip, thigh, or knee, which do not notably inhibit the patient in his everyday activities. From a therapeutic point of view, the most important thing is to make the diagnosis as soon as possible on the basis of the symptoms and signs by demonstrating restricted abduction and rotation in the hip joint and by X-raying the hips in the antero-posterior and in the Lauenstein view.

After a period of a slight reduction in epiphyseal growth and widening of the joint space as well as mild, relative epiphyseal sclerosis, linear translucency appears subchondrally in the anterior part of the epiphysis. This is rapidly followed by flattening of the epiphysis, starting anteriorly, and accompanied by increased bony density. Gradually, there is a general increase in the epiphyseal flattening. During the earliest radiological stage, in which epiphyseal height/width still constitutes more than 85% of the findings on the unaffected side, effective protection from weightbearing stands much better chances of affording a good result than after epiphyseal flattening has exceeded this limit. By early protection from weightbearing there are great possibilities of reducing the extent of the subsequent radiological changes and thereby the time elapsing until healing. Objective measurement of the degree of epiphyseal flattening and calculation of the initial quotient at the institution of treatment is a better method of prognostic classification than subjective evaluation of the radiological stage.

The analysis revealed a close relationship between the, incidentally somewhat uncertain, statements concerning duration of symptoms, the objective assessment of the radiological stage, and a subjective evaluation of the extent of fragmentation, but none between these parameters and sex or age.

Long-lasting protection from weightbearing aims at the regeneration of a spherical femoral head in as many hips as possible. This criterion is of the utmost importance in preventing subsequent osteoarthritis. Moreover, it is desirable that the spherical head should attain a shape as similar as possible to the unaffected side. This similarity may be measured by comparing the size relations of the two epiphyses by an epiphyseal quotient (EpQ), the size relations of the two joint surfaces as part of a sphere by a joint surface quotient (JsQ), and the degree of caput magnum by a radius quotient (RaQ).

Assessment of the sphericity of the head by template measurements must be done on X-ray films in the anteroposterior view and in Lauenstein's position, whereas measurement of the quotients on AP views is sufficient. The method of measurement and assessment is so reliable that two investigators who agree on the criteria arrive at results varying by only about 5%.

Spherical heads having a radius variation of less than 2 mm, whose JsQ and RaQ are within the range of a normal material, and whose EpQ exceeds 60% were classified as Excellent.

Other spherical heads were classified as Good, if the radius variation was within 2 mm.

Irregular heads with a radius variation of 2 - 4 mm were considered Fair.

More irregular heads were classified as Poor.

These measuring methods and this grading of the results were applied to the analysis of a material of 388 unilateral cases. Half the cases were treated as out-patients, 114 of them mainly in a wheelchair and 82 with the Thomas caliper. The other half were admitted to hospital, 79 of them treated with strict bed rest and thereafter with Snyder's sling, 113 with intermittent traction during bed rest followed by a period with Snyder's sling.

The results proved to be highly dependent upon age at institution of treatment and essentially upon the stage and the quality of protection from weightbearing.

In general the poorest therapeutic results were obtained in the patients treated with Thomas caliper and in that part of the wheelchair-treated patients (one-fifth) whose parents were unable to carry through the wheelchair regimen. But if only the treatment sitting in a wheelchair is observed in a way so that the patient never bears weight on the affected leg, this method gives results up to those of keeping the patients in bed in hospital. Only when bed rest was supplemented with intermittent traction during the first 12 months did this afford more effective protection and slightly better results. Treatment with wheelchair or with the bed rest methods proved equally effective in bilateral and in unilateral cases.

The very best results were obtained in a special, mild type of changes called dysplasia epiphysialis capitis femoris. All these cases obtained perfect healing, no matter which method had been used. Accordingly, these types should be treated by the gentlest non-weightbearing until it has been ascertained that the condition is not progressing into true LCPD which it well may, if no protection from weightbearing at all is applied. The condition is often combined with true LCPD changes in the other hip and is moreover rather often bilateral in the youngest patients.

Children who are not yet 5 years of age at the onset of LCPD attain spherical heads in a very high percentage of the cases, almost regardless of stage and quality of non-weightbearing. On the other hand, these two factors exert some influence upon the attainment of an excellent result. In these young children too, there is a free choice of the method of non-weightbearing which suits the patient and his family best.

Patients who are 9 years or over when the disease is detected, obtain a good result only if the disease runs a mild course, regardless of stage and quality of protection from weightbearing. At this age, the course does not appear to depend definitely upon stage or quality of non-weightbearing. In these patients, therefore, it is also permissible to select the gentlest method of non-weightbearing. In return, every effort should be made to carry through the treatment intensely and long enough in cases where the radiological epiphyseal changes assume only a mild degree. This affords quite good chances of attaining a spherical head.

In the largest age group, from 5 to 8 years, it is of the utmost importance to institute treatment at an early stage, before epiphyseal flattening has taken place. In that event, it is also permissible to select that method of non-weightbearing which suits the patient and his family best. If patients of this age range are already in a late stage with epiphyseal flattening at the time of diagnosis, they should be treated by the most effective protection from weightbearing, which is obtained by rest + traction in hospital. This method of treatment is the only one which can essentially reduce the risk of severe epiphyseal fragmentation and the consequently poorer result in such cases. According to the development of the changes, this treatment may be changed to a gentler regimen after a year or so.

In all cases where treatment in a wheelchair is selected, the parents as well as the patient must be carefully motivated for conscientiously observing this treatment by thorough instructions at its institution. They must know that the most important thing is to omit bearing weight on the legs, but that otherwise the treatment is a sitting regimen in which they are allowed to move about freely, only without getting up. The wheelchair is an aid for general daily transport, indoors as well as out. The strap is mainly an educational means for use until the patients have grown accustomed to the regimen.

At the outset at least, the families should be under the supervision of a socially and therapeutically interested adviser, who can help adjusting their daily life, mediate collaboration with the school, procure access to nursery school or recreation centre, and assess to what extent further wheelchairs, other aids, or possibly financial support are needed to carry through long-term protection from weightbearing under the existing home conditions.

As an out-patient method non-weightbearing in a wheelchair is just as practicable in urban as in rural environments, regardless of housing and social conditions.

In about one-fifth of the present cases the wheelchair regimen had not been adequately observed. It was not possible to elucidate the cause, but it is presumed to be related to temperament and upbringing. In cases where it is discovered that the wheelchair therapy cannot be carried through, because the patients are nevertheless bearing weight on the leg, they should quickly be admitted to hospital, at least those in an age range in which the quality of non-weightbearing has a marked influence upon the result.

The protection from weightbearing should be continued until it is apparent from the X-ray films that regeneration is definitely proceeding and the epiphyseal surface contours are visible. X-ray follow-up should be continued until the bone structure of the entire femoral head is normal. At that time the shape and structure of the head should be assessed,and all patients who have not attained sphericity of the femoral head should be followed further, with respect to choice of occupation and introduction to the social aids available.

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