High load injuries in the adolescent athlete's hip

CLINICAL AND EXPERIMENTAL STUDIES AND OUTCOME MEASURES

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To my family

ABSTRACT

Hip and groin symptoms are often a problem area in orthopaedics and sports medicine. Hip joint and groin pain and injuries are common among elite atheletes and in the increasingly active population. In recent years, femoroacetabular impingement (FAI) has emerged as one of the most common causes of hip and groin disability in young and active persons and it is a known risk factor in the development of osteoarthritis (OA) of the hip joint. Technical advancement and improved instruments have made surgical hip arthroscopy the mainstay treatment option in patients with debilitating FAI and the indications for hip arthroscopy are increasing.

The aetiology of FAI is still not completely known. Several theories have been proposed. One of them is that a growth disturbance in the proximal femur, caused by heavy loads during skeletal maturation, is a factor in the development of FAI. Moreoever, FAI has been reported as being more common in athletes in certain sports, leading to pain, reduced range of motion (ROM) of the hip joint and impaired athletic performance.

Despite the increased frequency of hip joint arthroscopic surgery, reliable and valid outcome measurements for the young and middle-aged, active patient with hip and groin pain have been lacking. Other instruments developed for older patients with osteoarthritis of the hip have been used, but their psychometric properties in this patient group are deficient.

In a clinical study, the morphological characteristics and ROM of the hips in a group of athletes were compared with those of a group of non-athletes. No difference in hip morphology was found between the groups, but the athletes had significantly less ROM and osteoarthritis was more common among the athletes.

The strength of the porcine proximal femoral physis was investigated in two biomechanical studies. The physeal plate was found to be the weakest point in the proximal femur. Injuries were seen after repeated physiological loading in and around the physeal plate both on MRI and histologically.

Two patient-reported outcome measurements (HR-PROMs) developed for this patient group, the iHOT12 and HAGOS, were found. Using a standardised methodology, the HR-PROMs were translated and adapted to Swedish. The Swedish versions were tested in a clinical study to measure their psychometric properties.

In conclusion, the morphological changes produced by FAI increase the risk of OA development in athletes. Injuries created in and around the physeal plate in the proximal femur during physiological loads can lead to morphological changes and ultimately FAI. The Swedish versions of the iHOT12 and HAGOS have good psychometric properties and can be used clinically and for research.

Keywords: hip joint, hip, groin, athlete, adolescent, femoroacetabular impingement, cam, pincer, osteoarthritis, porcine, epiphyseal plate, growth, validity, reliability, iHOT, HAGOS

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SAMMANFATTNING PÅ SVENSKA

Höft- och ljumskbesvär är vanliga bland elitidrottare och i den allt mer idrottsaktiva befolkningen. Höft- och ljumskbesvär har genom åren varit ett problemområde avseende diagnositk och behandling hos unga aktiva personer. Femoro-acetabular impingement (FAI) har de senaste åren beskrivits som vanlig orsak till höft- och ljumskbesvär bland aktiva personer och är en känd riskfaktor för utveckling av osteoartros i höftleden. FAI orsakas av en abnormal morfologi av antingen acetabulum, så kallad pincer förändring, eller lårbenshalsen såkallad cam förändring. Tekniska framsteg och bättre instrument har lett till att artroskopisk kirurgi av höftleden har blivit ett standard ingrepp och den vanligaste behandlingen av FAI. Indikationer för höftledsartroskopi har ökat.

Orsaken till den abnormala morphologin som leder till FAI är fortfarande inte helt känd. Flera teorier finns beskrivna. En av de vanligaste teorierna som framhålls är att tung belastning av höftleden under tillväxten leder till utveckling av cam förändringen. Förekomsten av cam är vanligare hos vissa idrottare än hos de som inte idrottat. Cam förändring leder till smärta, stelhet och i många fall minskad idrottsprestation. Trots allt fler artroskopiska ingrepp av höftleden, finns det inga validerade utfallsmått på svenska för denna grupp patienter, unga och aktiva. De utfallsmått, som används är framtagna för äldre patienter med artros och har sämre psykometriska egenskaper i den yngre, mer aktiva patientkategorin.
De morfologiska egenskaperna och rörelseomfånget av höftlederna jämfördes mellan en grupp elitidrottare och en grupp icke-idrottare i en klinisk studie. Ingen skillnad förelåg i morfologin men sämre rörelseomfång och mer artrosförändringar förekom hos idrottarna.

Styrkan av den proximala femoral physen (tillväxtplattan) hos unga grisar analyserades i två biomekaniska studier. Physen visade sig vara det svagaste området vid belastning i tre olika riktningar. Cyklisk belastning orsakade skador i och omkring physen som detekterades både på MRI och histologiskt.

Två patient-rapporterade utfallsmått, utvecklade för unga och aktiva patienter med höft- och ljumskbesvär, iHOT12 och HAGOS, översattes och anpassades till svenska på ett standardiserat sätt. De svenska versionerna testades i en klinisk studie för att värdera deras psykometriska egenskaper.

Sammanfattningsvis, förekomsten av cam förändring ökar risken för utveckling av artros i höftleden. Skador som uppkommer i och omkring physen i proximala femur under physiologisk belastning kan leda till utveckling av cam. Svenska versionerna av iHOT12 och HAGOS har goda psykometriska egenskaper och kan användas i klinisk vardag och för forskning.

CONTENTS

LIST OF PAPERS

This thesis is based on the following studies, referred to in the text by their Roman numerals.

I. Jónasson P, Thoreson O, Sansone M, Svensson K, Swärd A, Karlsson J, Baranto A. The morphologic characteristics and range of motion in the hips of athletes and non-athletes.
Submitted.

II. Jónasson P, Ekström L, Swärd A, Sansone M, Ahldén M, Karlsson J, Baranto A. Strength of the porcine proximal femoral epiphyseal plate: the effect of different loading directions and the role of the perichondrial fibrocartilaginous complex and epiphyseal tubercle – an experimental biomechanical study.
J Exp Orthopaedics 2014; 1:4.

III. Jónasson P, Ekström L, Hansson H-A, Sansone M, Karlsson J, Swärd L, Baranto A. Cyclical loading causes injury in and around the porcine proximal femoral physeal plate: proposed cause of the development of cam deformity in young athletes.
J Exp Orthopaedics 2015; 2:6.

IV. Jónasson P, Baranto A, Karlsson J, Swärd L, Sansone M, Thomeé C, Ahldén M, Thomeé R. A standardised outcome measure of pain, symptoms and physical function in patients with hip and groin disability due to femoroacetabular impingement: cross-cultural adaptation and validation of the international Hip Outcome Tool (iHOT12) in Swedish.
Knee Surg Sports Traumatol Arthrosc 2014; 22(4): 826-34.

V. Thomeé R, Jónasson P, Thorborg K, Sansone M, Ahldén M, Thomeé C, Karlsson J, Baranto A. Cross-cultural adaptation to Swedish and validation of the Copenhagen Hip and Groin Outcome Score (HAGOS) for pain, symptoms, and physical function in patients with hip and groin disability due to femoro-acetabular impingement.
Knee Surg Sports Traumatol Arthrosc 2014; 22(4): 835-42.

ADDITIONAL PUBLICATIONS

Ahlden M, Sansone M, Jonasson P, Sward L, Karlsson J (2014) [Hip arthroscopy, new technique against hip pain].
Lakartidningen 111 (36):1445-1449

Sansone M, Ahlden M, Jonasson P, Sward L, Eriksson T, Karlsson J (2013) Total dislocation of the hip joint after arthroscopy and ileopsoas tenotomy.
Knee Surg Sports Traumatol Arthrosc 21 (2):420-423.

Sansone M, Ahlden M, Jonasson P, Thomee C, Sward L, Baranto A, Karlsson J, Thomee R (2014a) A Swedish hip arthroscopy registry: demographics and development.
Knee Surg Sports Traumatol Arthrosc 22 (4):774-780.

Sansone M, Ahldén M, Jonasson P, Thomeé C, Swärd L, Baranto A, Karlsson J, Thomeé R (2015) Good Results After Hip Arthroscopy for Femoroacetabular Impingement in Top-Level Athletes. Orthopaedic
Journal of Sports Medicine 3 (2), doi:10.1177/2325967115569691

Sansone M, Ahlden M, Jonasson P, Thomee R, Falk A, Sward L, Karlsson J (2014b) Can hip impingement be mistaken for tendon pain in the groin? A long-term follow-up of tenotomy for groin pain in athletes.
Knee Surg Sports Traumatol Arthrosc 22 (4):786-792.

ABBREVIATIONS

COSMIN	COnsensus-based Standards for the selection of health Measurement INstruments
CT	Computed Tomography
EQ-5D	Euro Qol-5 Dimensions
ES	Effect Size
ET	Epiphyseal Tubercle
FABER	Flexion ABduction External Rotation
FADDIR	Flexion ADDuction Internal Rotation
FAI	Femoroacetabular Impingement
GPE	General Perceived Effect
HAGOS	Copenhagen Hip and Groin Outcome Score
HHS	Harris Hip Score
HOOS	Hip dysfunction and Osteoarthritis Outcome Score
HOS	Hip Outcome Score
HR-PRO	Health-Related-Patient Reported Outcome
HR-PROM	Health-Related-Patient Reported Outcome Measure
HSAS	Hip Sports Activity Score
ICC	Intraclass Correlation Coefficient
iHOT	International Hip Outcome Tool
mHHS	Modified Harris Hip Score
MIC	Minimal Important Change
MID	Minimal Important Difference
MRI	Magnetic Resonance Imaging
OA	Osteoarthritis
PFC	Perichondrial Fibrocartilagenous Complex
ROM	Range Of Motion
SD	Standard Deviation
SDC	Smallest Detectable Change
SEM	Standard Error of Mean
SRM	Standardised Response Mean
VAS	Visual Analogue Scale

BRIEF DEFINITIONS

Cam-type impingement	A type of femoroacetabular impingement where asphericity of the femoral head-neck junction results in the abutment of the aspherical head-neck junction on and under the acetabular rim during movement of the hip joint.
Ceiling effect	When a significant number of subjects obtain the highest score, an instrument is able to measure and the instrument is thus unable to detect an upward change.
Construct	A subjective phenomenon such as pain, function or quality of life. A construct is frequently measured with multiple items.
Construct validity	The degree to which the scores of an instrument are consistent with hypotheses (for instance, with regard to internal relationships, relationships to scores of other instruments, or differences between relevant groups) based on the assumption that the HR-PRO instrument validly measures the construct to be measured.
Content validity	The degree to which the content of an instrument is an adequate reflection of the construct to be measured.
Criterion validity	The degree to which the scores of an HR-PRO instrument are an adequate reflection of a 'gold standard'.
Cross cultural validity	The degree to which the performance of the items on a translated or culturally adapted instrument are an adequate reflection of the performance of the items of the original version of the HR-PRO instrument.
Diaphysis	The midsection or shaft of long bones. Lies between the metaphyses and contains the primary centre of ossification.
Enchondral ossification	Bone is formed from hyaline cartilage. Most long bones of the body and the spine are formed by enchondral ossification.
Epiphyseal tubercle	A bony peg on the underside of the epiphysis projecting into a socket on the metaphysis. It is usually more prominent in animals than in humans.
Epiphysis	The rounded end of a long bone. The epiphysis usually articulates with an adjacent bone forming a joint. The epiphysis usually contains one or more secondary centres of ossification that grow spherically by enchondral ossification.
Face validity	The degree to which the items of an instrument look as though they adequately reflect the construct to be measured.
Femoroacetabular impingement	A syndrome of symptoms caused by the impingement of the femoral head-neck junction on and/or under the acetabular rim.
Floor effect	When a significant number of subjects obtain the lowest score, an instrument is able to measure and the instrument is thus unable to detect a downwards change.

Health-Related Patient-Reported Outcome Measure	Questionnaire completed by patients to measure perceptions of their general health or their health in relation to a specific illness or condition.
Internal consistency	The degree of interrelatedness between different items of an instrument.
Interpretability	The degree to which qualitative meaning can be assigned to the quantitative score or change in scores of the instrument.
Intramembranous ossification	Bone is formed from mesenchymal or connective tissue. The flat bones of the skull, the maxilla, mandible and clavicles are formed by intramembranous ossification.
Item	A single question or statement in an HR-PRO.
Likert scale	A measurement instrument for subjective phenomena that cannot be directly measured. Level of agreement or disagreement is indicated by a mark on a symmetrical, agree-disagree scale with a series of statements.
Measurement error	Systematic or random error of an instrument.
Metaphysis	Wide portion of long bones between the physis and diaphysis.
Osteoarthritis	Also called degenerative arthritis or osteoarthrosis. A degenerative joint disease that results in the breakdown of the joint cartilage. In secondary osteoarthritis, the underlying cause is known, but, in primary osteoarthritis, the cause is unknown.
Perichondrial fibrocartilagenous complex	At the periphery of the physis, the zone of Ranvier is responsible for the horizontal growth of the physis and the ring of Lacroix provides the mechanical stability of the physis. In the proximal femoral physis, the zone of Ranvier and the ring of Lacroix are replaced by the PFC.
Physis	The growth plate or epiphyseal plate. The physis is located between the epiphysis and metaphysis in long bones of growing individuals. Most of the growth in length occurs in the physis through enchondral ossification.
Pincer-type impingement	A type of femoroacetabular impingement, where local or global overcoverage of the acetabulum on the femoral head results in the femoral neck pressing against the acetabular rim during movement of the hip joint.
Range of movement	The measured movement over a joint in degrees.
Reliability	The degree to which a measurement is free from measurement error. The extent to which scores for patients who have not changed are the same for repeated measurement under several conditions: e.g. using different sets of items from the same HRPRO (internal consistency); over time (test-retest); by different persons on the same occasion (inter-rater); or by the same persons on different occasions (intra-rater).
Responsiveness	The ability of an instrument to detect change over time.
Structural validity	The degree to which the scores of an instrument are an adequate reflection of the dimensionality of the construct to be measured.

Validity	The degree to which an HR-PRO instrument measures the construct(s) it purports to measure.
Visual analogue scale	A measurement instrument for subjective phenomena that cannot be directly measured. Agreement level with a statement is indicated by a mark on a continuous line between two end-points.

Páll Sigurgeir Jónasson

1

INTRODUCTION

INTRO-DUCTION

1. 1. THE HIP

1. 1. 1. Anatomy and biomechanics of the hip

The hip joint is a ball-in-socket joint, where the round femoral head articulates with the concave pelvic acetabulum. The ball-in-socket architecture of the hip joint allows movement in three planes, the sagittal plane (flexion and extension), the frontal plane (abduction and adduction) and the transverse plane (internal and external rotation). This is similar to the shoulder joint, but the need for stability is greater because of the larger loads imposed on the hip joint. The joint capsule that is reinforced by intrinsic ligaments mainly provides this stability, but at the same time it influences the possible range of motion (Figurer 1 and 2). The iliofemoral ligament lies anteriorly and limits extension, the pubofemoral ligament is located inferiorly and limits abduction and the ischiofemoral ligament is located posteriorly and limits internal rotation. The capsule is further enforced posteriorly by the annular ligament that is attached to the greater trochanter and runs circumferentially around the femoral neck. It plays an important role in resisting distractive forces (Wagner et al. 2012; Ito

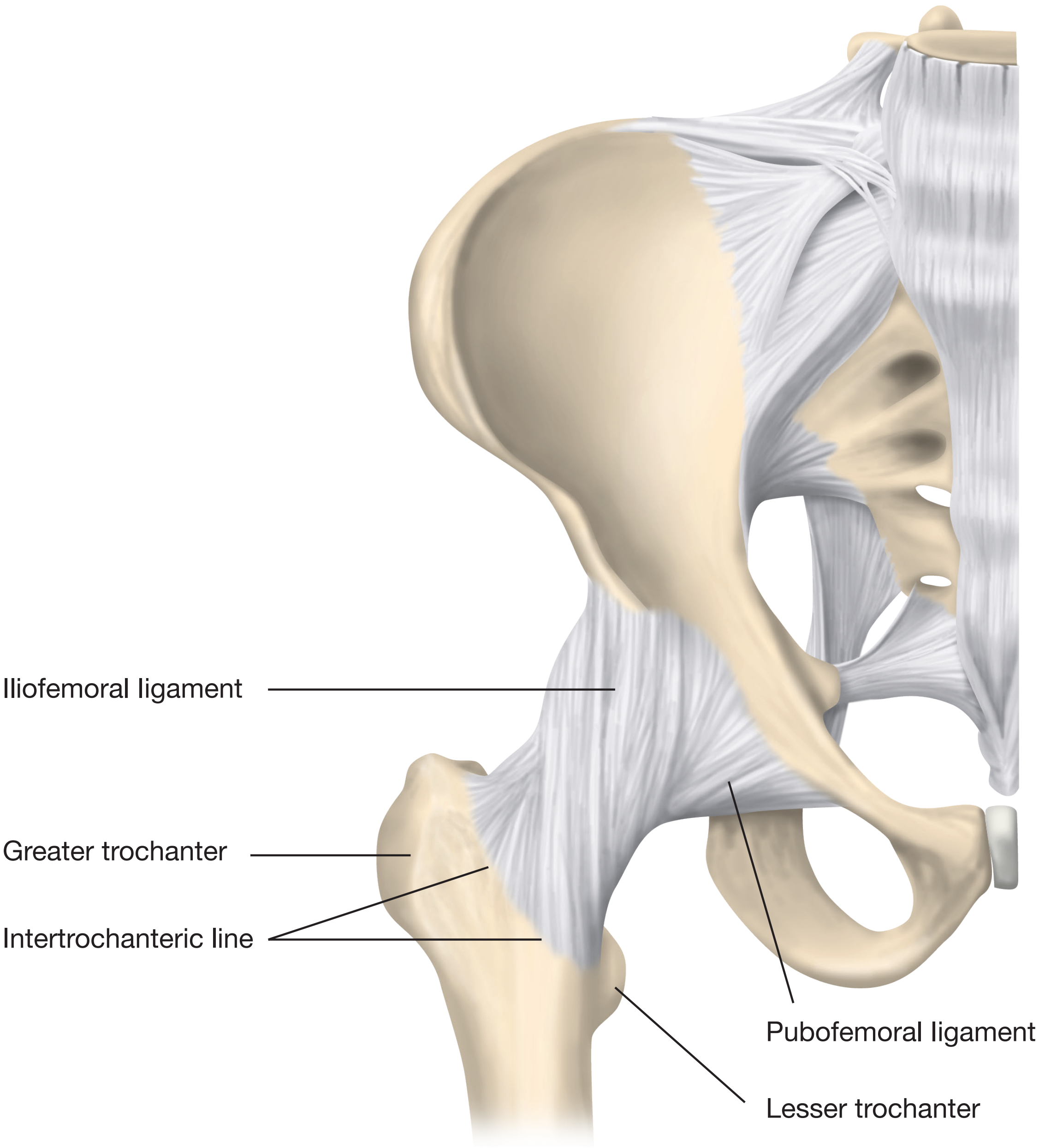

Figure 1 Anterior view of the right hip showing the bony anatomy and the ligaments of the hip joint.

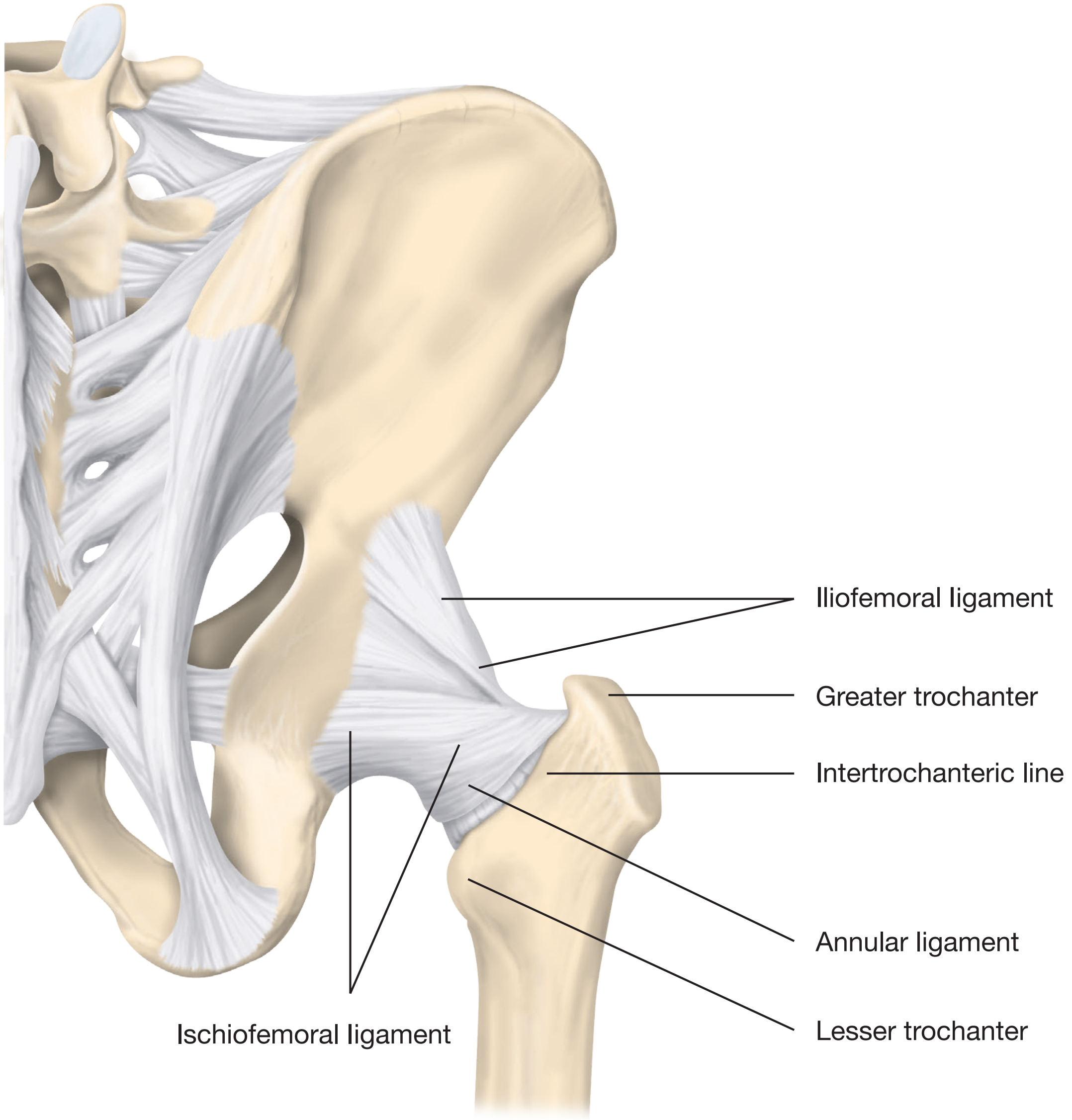

Figure 2 Posterior view of the right hip showing the bony anatomy and the ligaments of the hip joint.

et al. 2009). Along the bony circumference of the acetabulum, the fibrocartilagenous labrum is located. Superiorly, it is continuous with the acetabular cartilage, but, inferiorly, its anterior and posterior portions are connected together by the transverse ligament. It increases joint depth, providing increased stability and joint congruity (Grant et al. 2012; Ferguson et al. 2000). From the transverse ligament and the inferior margin of the acetabulum, the ligamentum teres arises. It inserts into the fovea capitis of the femoral head and forms the only intra-articular connection between the pelvis and the femur (Figure 3). It was previously believed to be a vestigial structure, but it has now been suggested that the ligamentum teres functions as an intrinsic stabiliser of the hip (Cerezal et al. 2010).

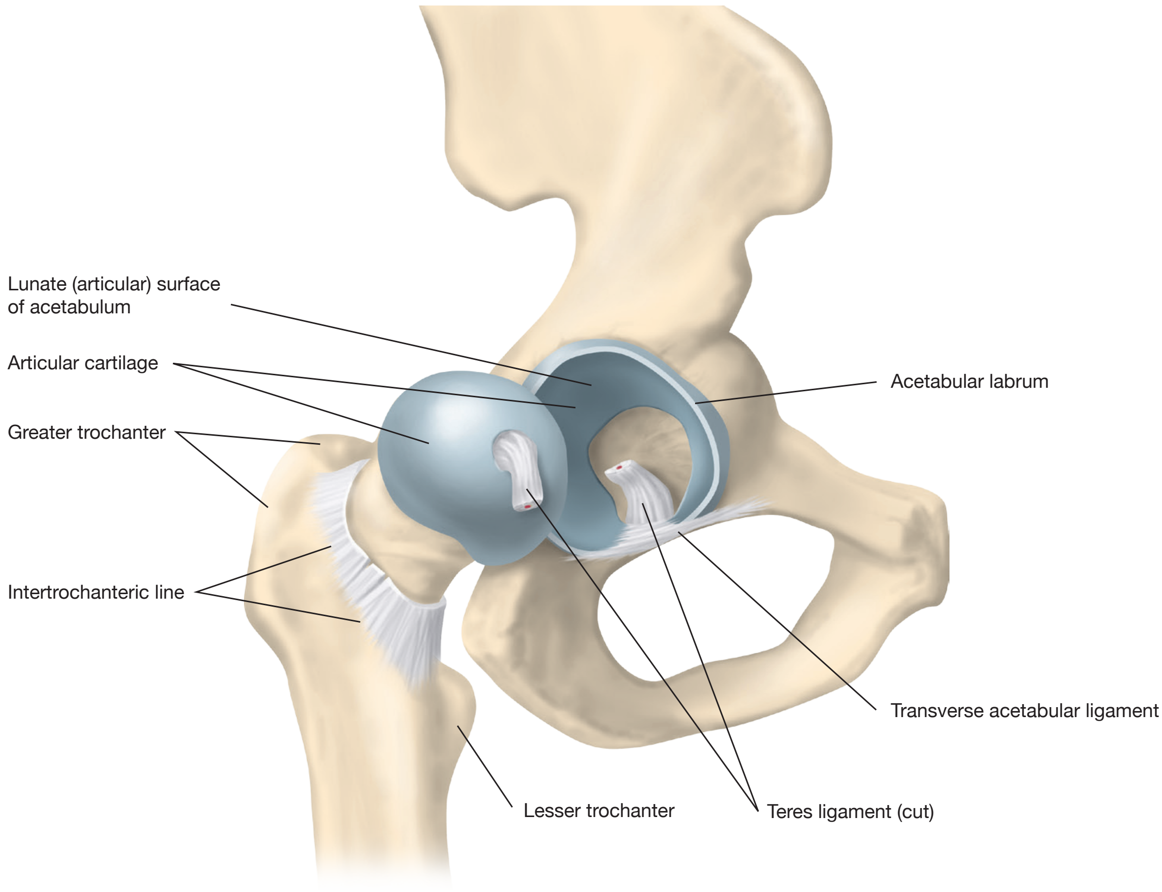

Figure 3 Lateral view of the right hip showing the bony anatomy, the labrum and the teres ligament (cut). The joint capsule has been removed and the femoral head is dislocated posteriorly to show the acetabulum and its anatomy.

1. 1. 2. Osteoarthritis

The aetiology of osteoarthritis (OA) is the subject of debate. Degenerative arthritis with a known underlying cause, such as trauma, infection, osteochondritis dissicans or morphological changes, is referred to as secondary osteoarthritis. A more common scenario in which no underlying cause is found is called primary osteoarthritis. With increasing knowledge and investigations, more underlying causes of hip osteoarthritis have been identified and mechanical factors are now believed to be a common cause of secondary osteoarthritis (Harris 1986).

Elmslie (1933) saw that, in many patients who developed hip osteoarthritis at an early age, an underlying hip joint deformity, which he termed coxa plana, was present. He hypothesised that the change in biomechanics caused by a misfit between the femoral head and acetabulum led to degenerative changes in the hip joint (Elmslie 1933). At a laterstage, Murray et al. described the tilt deformity and Stulberg et al. described the pistol-grip deformity of the femoral head as a possible cause of hip osteoarthritis (Murray 1965; Stulberg SD et al. 1975).

What Elmslie called coxa plana in 1933, Murray called tilt deformity in 1965 and Stulberg named pistol-grip deformity in 1975 is now generally referred to as cam deformity.

1. 1. 3. Femoroacetabular impingement

Two types of femoroacetabular impingement (FAI) have been described, the cam type and the pincer type. The cam deformity is a non-spherical shape of the femoral head at the femoral head-neck junction. It usually resides on the antero-superior surface and leads to a reduced offset of the femoral neck and abutment of the head-neck junction against the acetabular rim, causing FAI. A pincer type is characterised by the impact of the femoral head-neck junction on the acetabular rim that protrudes locally (as in acetabular retroversion) or globally (as in coxa profunda), creating overcoverage of the femoral head. Mixed type FAI often occurs with both a cam deformity and a pincer (Figure 4). Although the pincer type of FAI leads to labral injury and cartilage damage, its

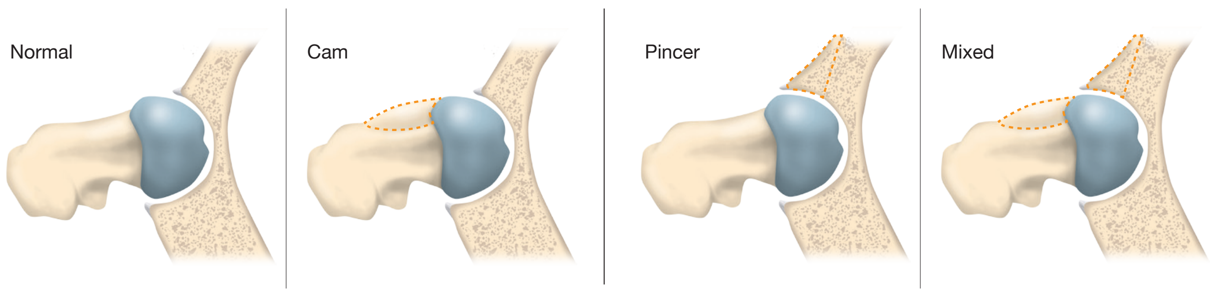

Figure 4 Horizontal view of a left hip showing the different types of femoroacetabular impingement.

role in the development of osteoarthritis is unclear (Beck et al. 2005). Everything from an increased risk of osteoarthritis development to a protective effect against the development of osteoarthritis has been seen in different studies of patients with pincer-type FAI. Agricola et al. found that acetabular dysplasia, defined as an anterior or lateral CE angle (ACE and LCE respectively) of under 25°, increased the risk of osteoarthritis, but a pincer deformity, defined as ACE or LCE over 40°, reduced the risk of osteoarthritis at a five-year follow-up (Agricola et al. 2013b). Bardakos et al. and Giori et al. found that acetabular retroversion, defined as a cross-over sign and/or a posterior wall sign, increased the risk of osteoarthritis, while Reynolds et al. found that acetabular retroversion was a common cause of hip pain (Giori and Trousdale 2003; Bardakos and Villar 2009; Reynolds et al. 1999). There is, on the other hand, increasing evidence that the cam deformity leads to OA of the hip (Ganz et al. 2003; Beck et al. 2005). In two case-control studies, an increased risk of OA development was found in patients with pistol grip deformity (Doherty et al. 2008; Nicholls et al. 2011). In a nationwide prospective cohort study, Agricola et al. saw that the cam deformity was a risk factor in the development of OA and, the greater the deformity, the higher the risk (Agricola et al. 2013a).

The aetiology of the cam deformity is still unknown. Theories, including evolutionary (Hogervorst et al. 2011), genetic factors (Pollard et al. 2010), abnormal ossification of the proximal femur (Murray 1965) and growth disorder or childhood condition, like a silent capital slip or Perthes disease (Goodman et al. 1997; Harris 1986; Murray 1965; Stulberg SD et al. 1975), have been proposed.

In recent years, evidence has emerged supporting mechanical factors, affecting the proximal femoral physis, as a cause of cam deformity. As early as 1971, Murray showed that the tilt deformity was more prevalent in individuals who were more active in sports during adolescence as compared with their less active peers (Murray and Duncan 1971). The cam deformity has been shown to emerge from the physeal scar of the proximal femoral physis (Siebenrock et al. 2004) and to develop during adolescence in response to vigorous sporting activity (Agricola et al. 2012; Siebenrock et al. 2013; Agricola et al. 2014; Tak et al. 2015).

1. 1. 4. The athlete's hip

The importance of physical exercise for general health and well-being is undisputed. Among both adults and adolescents, often from a low age, participation in sports and sports-related recreational activities has increased in recent years (Jones et al. 2001).

Hip and groin pain is common in athletes. Diagnosis is often difficult. Differential diagnoses include referred pain (lumbar pain, pelvic pain), extra-articular causes (bursitis, piriformis syndrome, hernia) and intra-articular causes (labral and chondral injuries, loose bodies, synovitis, avascular necrosis).

FAI is a common cause of hip and groin pain and reduced range of motion (ROM) and performance in the athlete (Siebenrock et al. 2004) and osteoarthritis is more common in athletes than the general population (Gouttebarge et al. 2015).
The adult athlete and the adolescent athlete suffer many of the same muscular and skeletal injuries, but, with closed growth plates, the adult athlete does not suffer from growth plate or apophyseal injuries.

1. 1. 5. The adolescent athlete

In the USA, it is estimated that more than 30 million children participate in sports (Adirim and Cheng 2003). In Great Britain, 75% of children between five and 15 years of age participate in organised sport, while 11% are involved in intensive training (Maffulli and Bruns 2000).

The actual incidence of adolescent sports-related injuries is difficult to determine, but there are indications that it is on the rise, for both acute and chronic injuries (Adirim and Cheng 2003; Damore et al. 2003).

Adolescent athletes suffer many of the same injuries as their adult counterparts, but, due to their growing skeletal system, the growth plates and apophysis are particularly at risk of injuries. Approximately 15% of all fractures in children involve the growth plate and about half the growth plate injuries occur during competitive or recreational sports (Ogden 1981; Peterson et al. 1994). A slipped capital femoral epiphysis is the most common hip disorder in adolescents, with an incidence of aproximately two cases per 100,000 (Crawford 1988).

Acute physeal and apophyseal injuries to both upper and lower extremities and in the spine are seen in athletes (Caine et al. 2006; Koehler et al. 2014; Maxfield 2010).

At an early age, many athletes choose to make a career from their sport. The dream of fame and fortune as an elite athlete attracts many children and adolescents to train a single sport intensively over long periods and at a young age. There is gathering evidence that this repetitive, strenuous and often monotonous physical exercise in a growing individual leads to musculoskeletal morbidity and/or disturbed growth (Adirim and Cheng 2003; Caine et al. 2006; Habelt et al. 2011; Maffulli et al. 2010).

Knowledge of growth disturbances and chronic physeal damage to the upper and lower extremites and the spine of adolescent elite athletes is well established (Caine et al. 2006; Epstein and Epstein 1991; Lundin et al. 2001; Maffulli et al. 2010; Swärd et al. 1990; Baranto et al. 2006).

1. 1. 6. Hip examination of athletes with FAI

The most common complaint among athletes with FAI is that of groin pain with, or exacerbated by, physical activity or periods of hip flexion. The pain can radiate medially to the symphysis, laterally to the trochanter area or dorsally to the gluteal area. In certain cases, the symptoms are more subtle and diffuse and the patient has often been seen by many specialists, especially physiotherapists, and has undergone different treatments to try to alleviate the symptoms (Burnett et al. 2006; Sansone et al. 2014).

The most common finding when examining the FAI patient is reduced ROM, particularly flexion and internal rotation (Audenaert et al. 2012; Clohisy et al. 2009b). Several clinical tests have been described to help in the diagnosis of FAI. Most of the tests are fairly sensitive, but they are often lacking when it comes to specificity (Tijssen et al. 2012). The anterior impingement test or FADDIR (flexion adduction and internal rotation) and Patrick's sign or FABER (flexion abduction and external rotation) are the most commonly reported tests with the log roll test (Figures 5, 6 and 7).

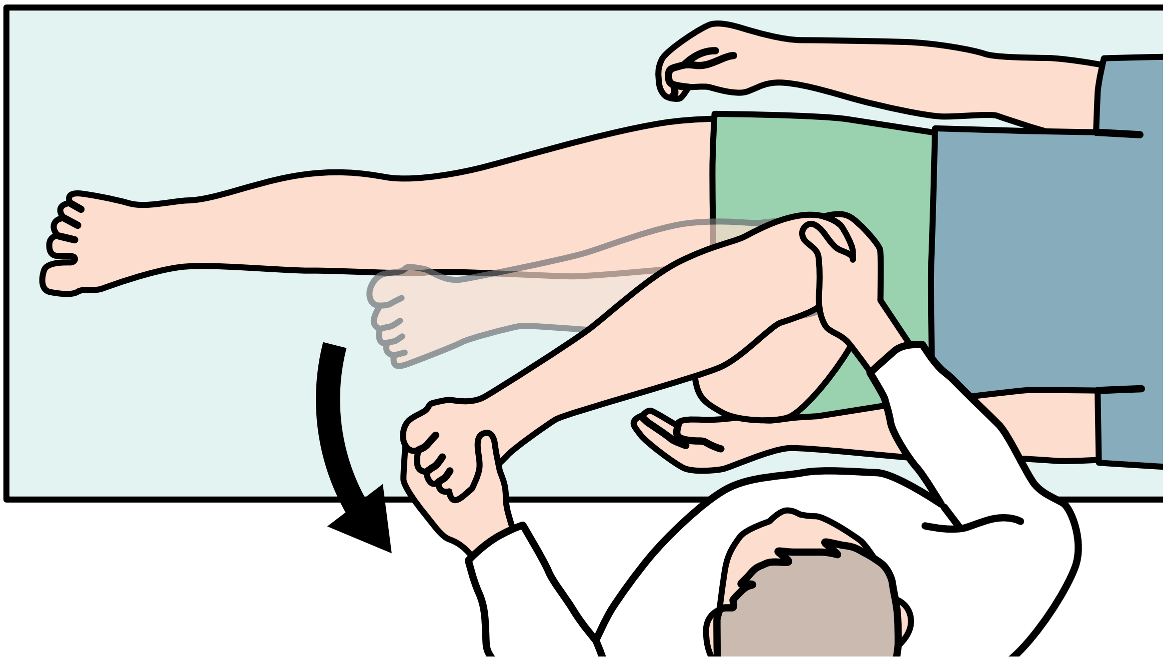

Figure 5 The FADDIR test is performed with the patient supine. The hip is flexed to 90°, adducted and inrotated at the same time. The reproduction of patient symptoms means the test is positive.

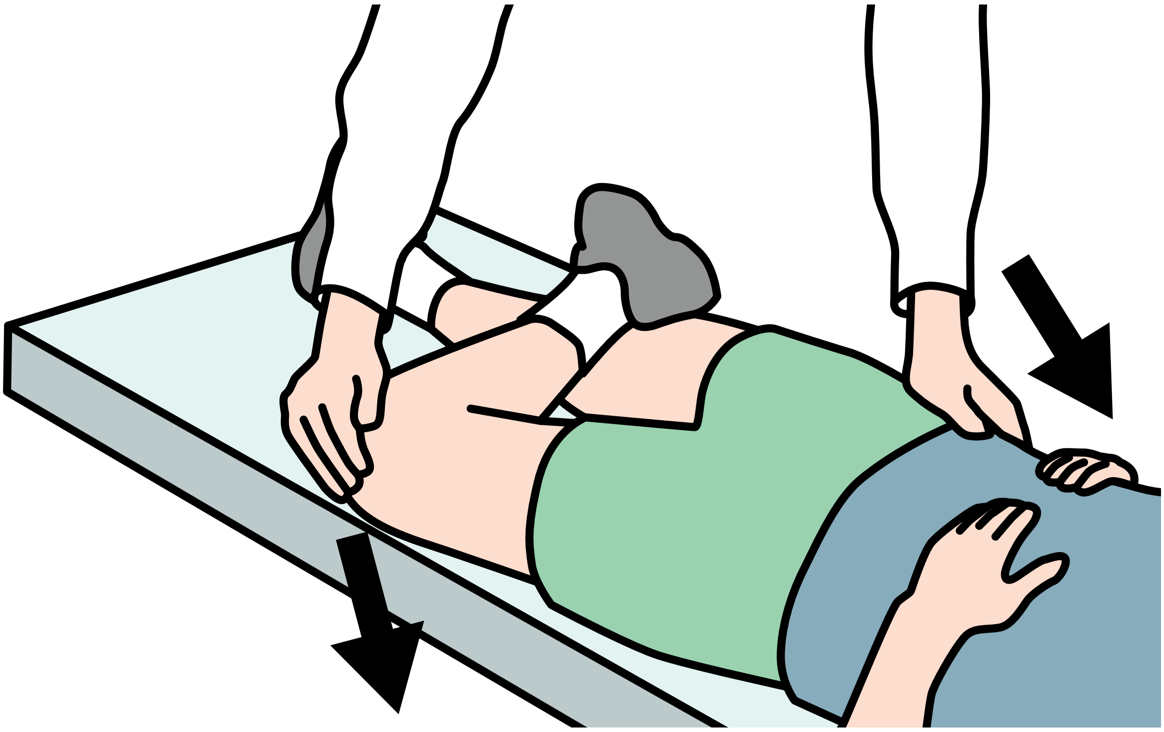

Figure 6 The FABER test is performed with the patient supine. The lateral malleolus of the examined hip is placed superiorly to the patella of the contralateral knee. The hip is then abducted with one hand, while the pelvis is stabilised with the other hand. The reproduction of symptoms means the test is positive. The angle between the examination table and the lower leg of the examined extremity can be registered as an indication of range of motion.

Figure 7 The log roll test is performed with the patient supine. The examined extremity is rotated in the neutral position between maximum external and internal rotation. The reproduction of symptoms means the test is positive. The range of motion can also be registered and compared with the unaffected side.

1. 1. 7. Imaging the hip of athletes with FAI

The diagnosis of femoroacetabular impingement cannot be made without radiological investigation. a standard plain radiograph with an AP and lateral view of the hip is often sufficient, but the cam deformity is usually best visualised on a Dunn's view or a Lauenstein view (Clohisy et al. 2007; Barton et al. 2011) (Figure 8).

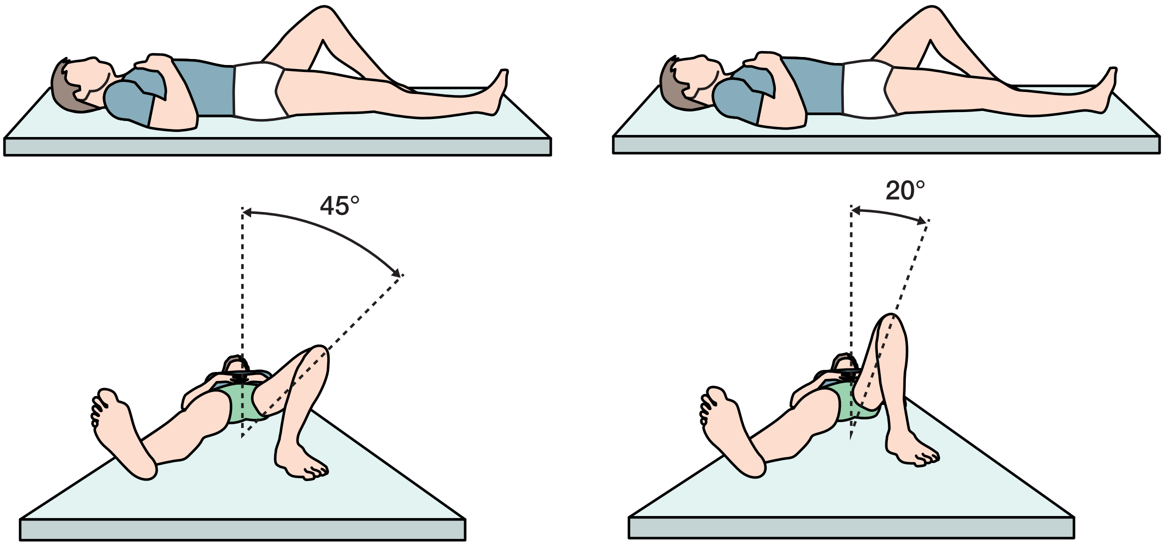

Figure 8 In addition to standard radiographic projections, the Dunn view(right image) or the modified Lauenstein view(left image) are often necessary to visualise the cam deformity. Both are performed with the patient supine and the hip flexed at 45°. The Dunn view is acquired with 20° abduction and the modified Lauenstein with 45° abduction.

Quantification of the asphericity of the femoral head is usually made by measuring the alpha angle. The alpha angle can be measured on plain radiographs, computed tomography (CT) and magnetic resonance imaging (MRI) (Notzli et al. 2002). Other measurements, such as head-neck offset, offset ratio (Eijer et al. 2001) and the triangular index (Gosvig et al. 2007), have been described, but they are not as commonly reported as the alpha angle (Figure 9)

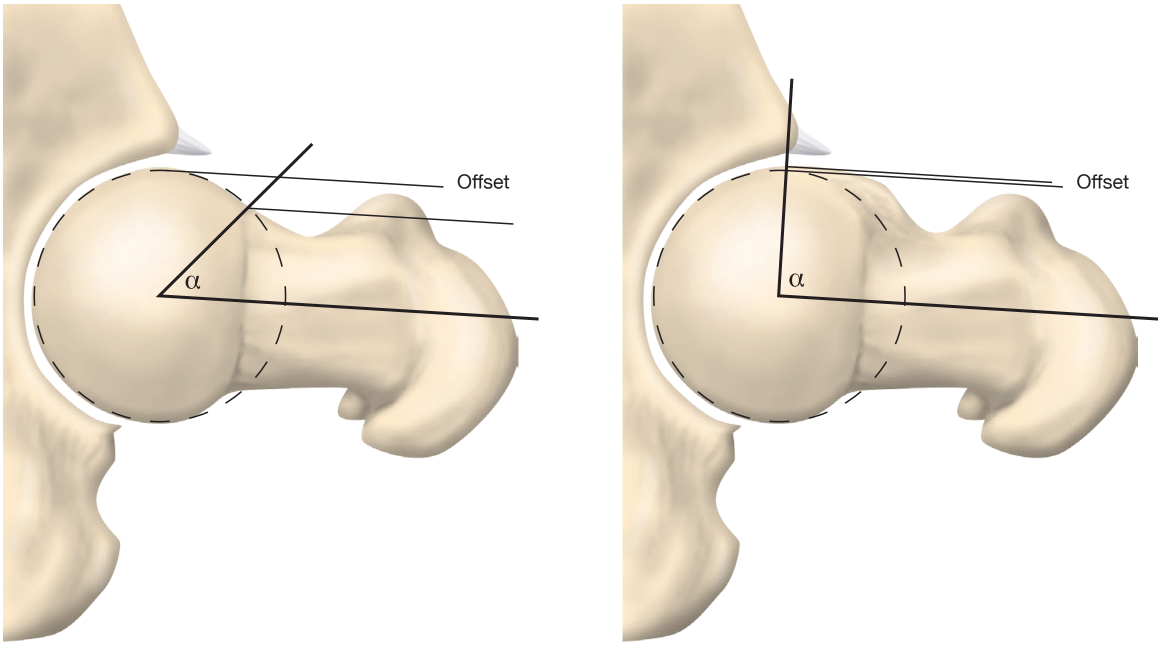

Figure 9 The alpha angle quantifies the cam deformity. It is the angle between two lines drawn from the centre of the femoral head. One line is drawn along the centre of the femoral neck and the other to the point at which the bone breaks through a best-fit circle around the femoral head. Alpha angles larger than 60° are deemed pathological. The offset is measured as the distance between two lines drawn parallel to the femoral neck, one from the outer diameter of the femoral head and the other from the point at which the bone breaks through the best-fit circle. The offset ratio is measured as the ratio between the offset and the femoral head diameter.

Overcoverage of the acetabulum on the femoral head is routinely expressed as the centre edge (CE) angle and/or acetabular index (Wiberg 1939; Tannast et al. 2007) (Figure 19). Acetabular retroversion can be expressed as the cross-over sign, posterior wall sign and/or ischial spine sign (Kalberer et al. 2008; Reynolds et al. 1999). (Figure 11).

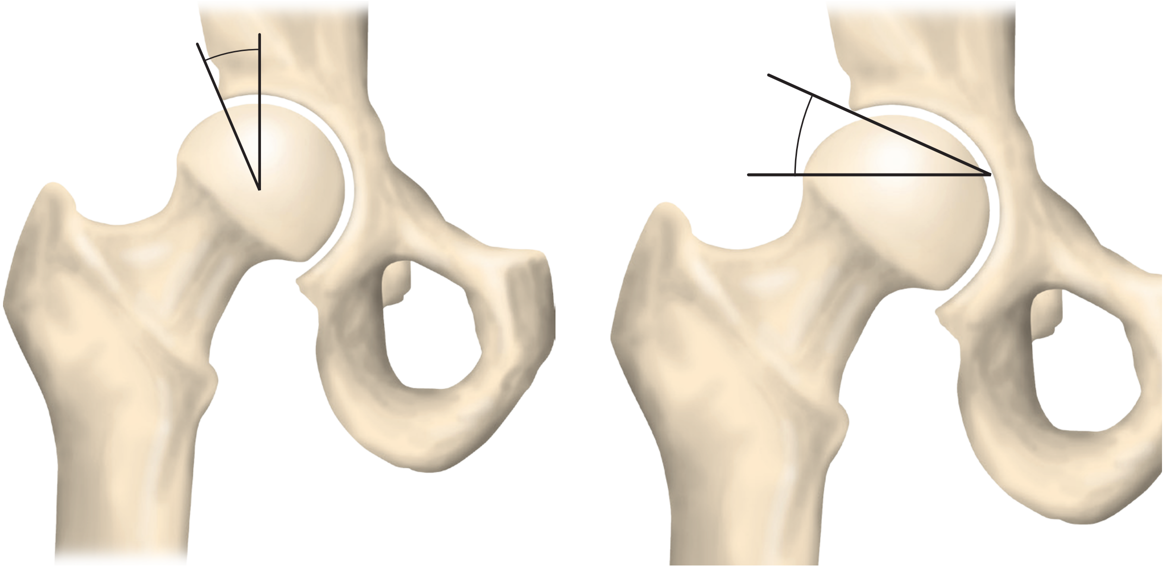

Figure 10 The centre-edge angle (left image) is measured as the angle between a vertical line and a line drawn from the centre of the femoral head to the lateral border of the acetabulum. The acetabular index, or Tönnis angle (right image), is measured as the angle between a horizontal line and a line drawn from the medial to the lateral edge of the acetabular sourcil.

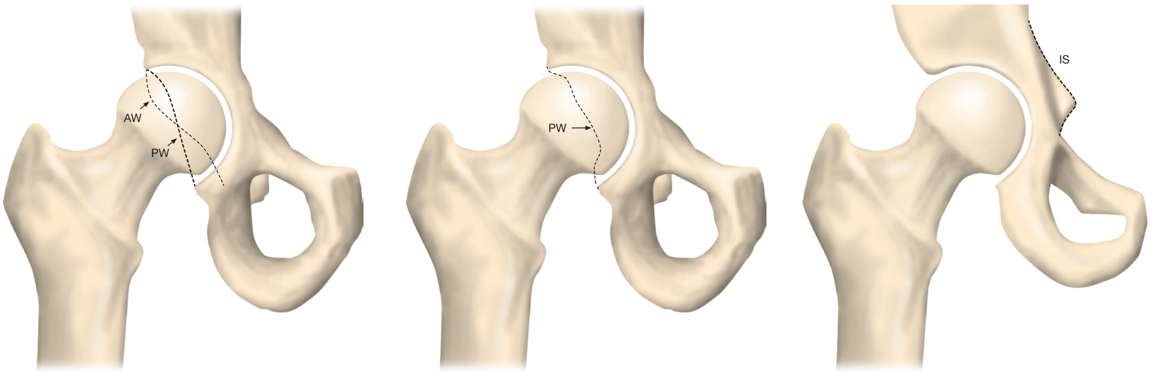

Figure 11 Three indications of a retroverted acetabulum, as seen on an AP pelvic view radiograph, shown here in a right hip. The cross-over sign (right image) is present when a line drawn along the anterior margin of the acetabulum crosses a line drawn along the posterior margin of the acetabulum. The posterior wall sign (middle image) is present when a line drawn along the posterior margin of the acetabulum lies medially to the centre of the femoral head. The ischial spine sign (right image) is present when the ischial spine projects medially from the pelvic brim towards the pelvic inlet.

Secondary signs of FAI often seen on plain radiographs are the linear indentation sign, herniation pits and ossification of the labrum and, finally, os acetabuli (Leunig et al. 2005; Beck et al. 2005) (Figures 12 and 13)

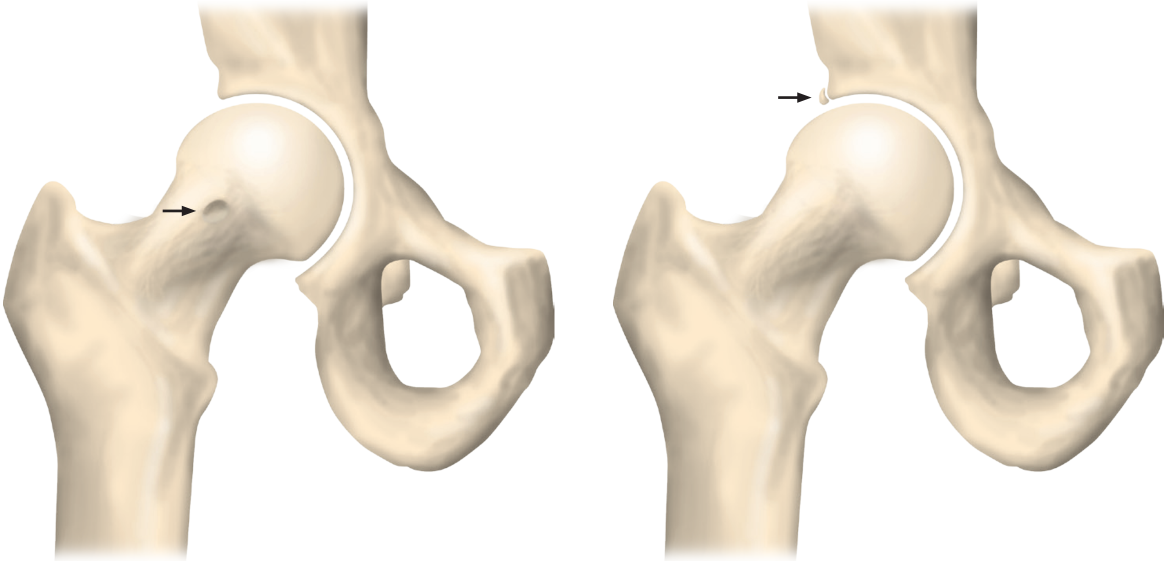

Figure 12 The herniation pit(left image), often found on the antero-superior head-neck junction of the proximal femur, and the os acetabuli(right image) on the superior margin of the acetabulum are common secondary signs of FAI.

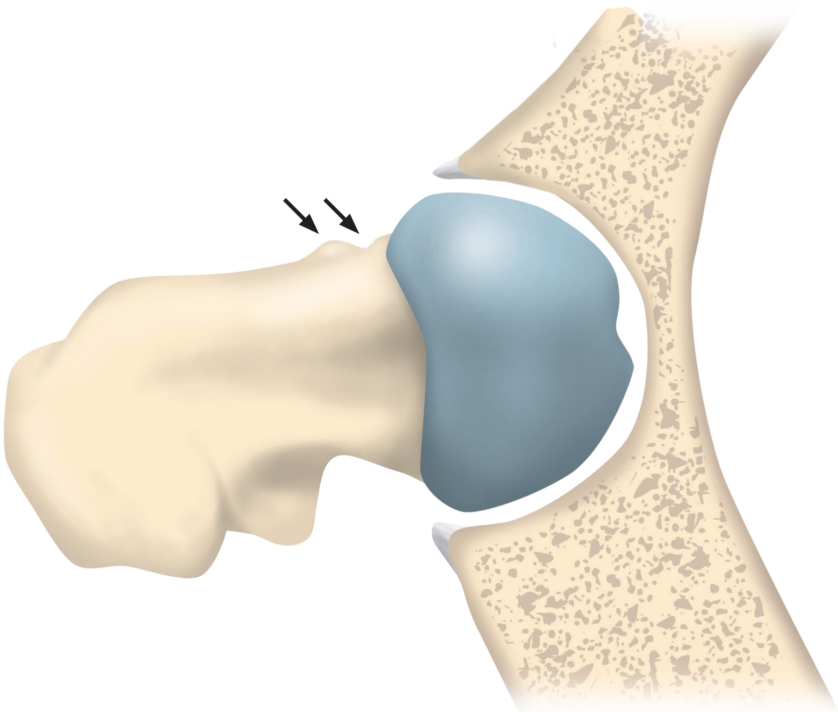

Figure 13 The linear indentation sign is often seen on the anterior femoral neck in the presence of a pincer deformity.

MRI and CT scans can be useful in revealing other causes of hip pain, such as tendon, cartilage and labrum damage, but they are seldom needed for the diagnosis of FAI. In the young athlete, MRI is favourable as it prevents unnecessary radiation of the growing body.

1. 2. SKELETAL GROWTH AND GROWTH DISTURBANCES

1. 2. 1. Historical aspects

Through the centuries, the knowledge that applying external loads can control growth has been used to cause bone deformities by artificial means. The Amazons were said to have separated the epiphyses from the metaphyses of newborn males to ensure female dominance and supremacy. The ancient Egyptians and certain American Indian tribes bound the heads of infants to produce elongation of the skull and, in China, the feet of young girls were bound to prevent further growth.

Through medical history, from the time of Hippocrates to the present day, the subject of bone growth and its disturbances has been discussed.

In the seventeenth century, the word "epiphysis" appeared in the English language. In the eighteenth century, an understanding of the importance of the physis began when Hales, in 1727, Duhamel, in 1742, and Hunter, in 1837, noted that long bones grew in length only at their ends. In 1858, Müller described the microscopic anatomy of the physis. In the nineteenth century, Ollier, Vogt and Hutchinson investigated the effects of injury to the physis. With Roentgen's discovery of the X-ray in 1895, the subject could be studied more scientifically and, in the twentieth century, knowledge increased rapidly (Nicholson and Nixon 1961; Trueta and Amato 1960; Bisgard 1933).

Although our understanding of bone growth is greater than in the days of Hippocrates, there is still a great deal to learn.

1. 2. 2. Bone anatomy and growth

Bone development occurs in two different ways. The bone is formed from either mesenchymal or connective tissue through intramembranous ossification or through enchondral ossification, where bone is formed from hyaline cartilage.

The flat bones of the skull and the mandible, maxilla and clavicles are formed by intramembranous ossification. The long bones and spine and most of the other bones in the body are formed by enchondral ossification (Figure 14).

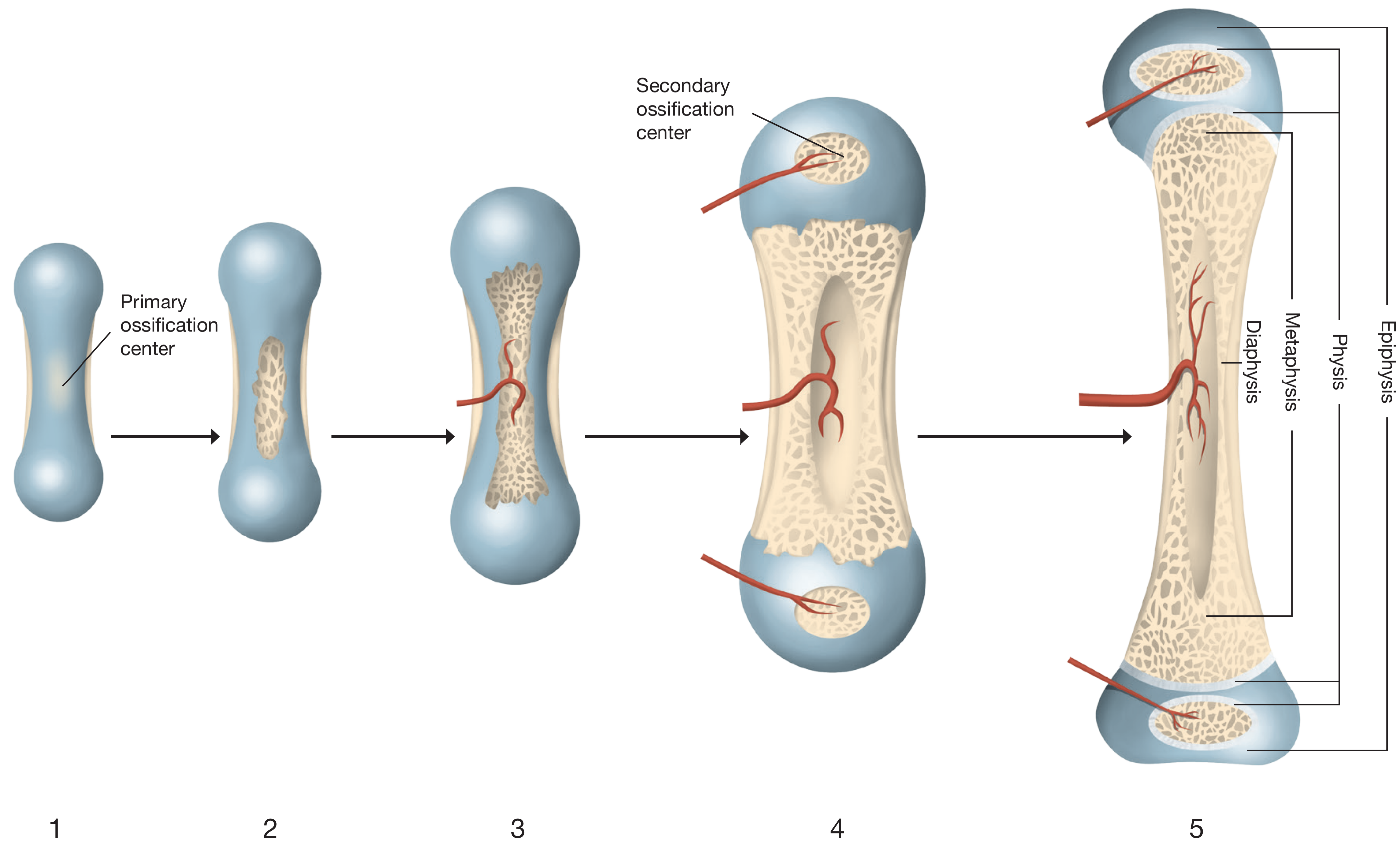

Figure 14 All the long bones in the body are formed by enchondral ossification, where a bone collar is formed around and a primary ossification centre forms inside a hyaline cartilage model (1). The cartilage matrix deteriorates (2) and spongious bone in formed (3). The secondary ossification centre forms in the epiphysis and is invaded by an epiphyseal artery (4). After ossification of the epiphyses, hyaline cartilage only remains in the epiphyseal plates and the articular cartilage. The long bone now consists of an epiphysis, physis, metaphysis and diaphysis (5).

All the long bones of a growing individual consist of an epiphysis, physis and metaphysis at each end, separated by the diaphysis.

The diaphysis is the primary centre of ossification. It grows circumferentially through appositional growth by the deposition of bone beneath the periosteum, but it does not grow longitudinally. The diaphysis is composed of lamellar bone with a strong cortical exterior.

The metaphysis is composed of spongious, trabecular bone with a thin exterior cortical bone. It connects the diaphysis with the adjacent physis.

The epiphysis is located on top of the physis and articulates with the adjacent bone. Almost all epiphyses contain one or more secondary ossification centres. These ossification centres grow spherically by enchondral ossification and are responsible for less than 5% of the growth in length.

The physis forms a discoid structure between the metaphysis and epiphysis. It is often referred to as the epiphyseal plate/line or growth plate/line. More than 95% of growth in the length of long bones occurs in the physis. When visualised under a microscope, it is a complex structure, with its cellular anatomy defined into different layers or zones (Figure 15). In the resting zone (also called the germinal or reserve zone) on the epiphyseal side, the stem cells accumulate and the storage of nutrients occurs. In the adjacent proliferative zone, the stem cells divide and differentiate into chondrocytes, oriented in columns (sometimes called the columnar zone). The chondrocytes then enlarge in size to form the hypertrophic zone. In the hypertrophic zone, the chondrocytes show increased metabolic activity and go into apoptosis. The dead chondrocytes are invaded by vascular channels from the metaphysis and the mineralisation of the intercellular matrix occurs in the calcification zone.

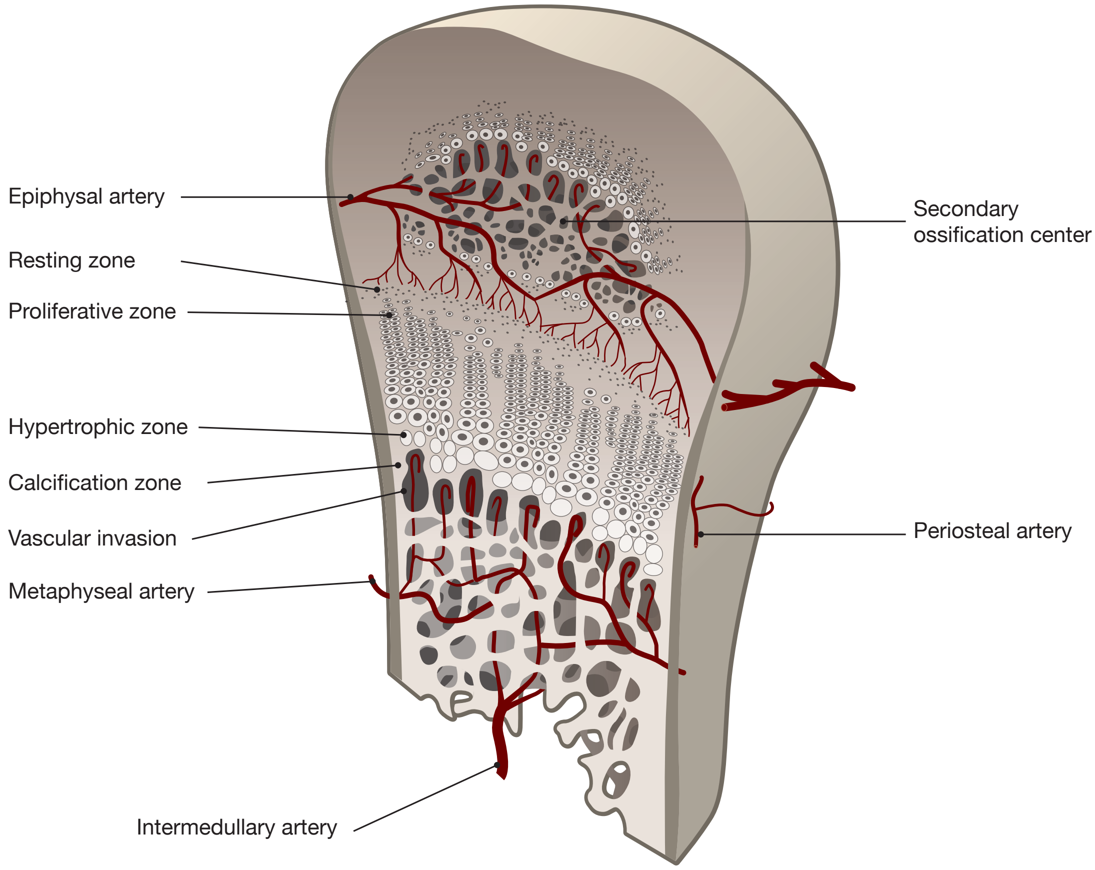

Figure 15 The physis is avascular, but oxygen and nutrients arrive from the epiphyseal and metaphyseal arteries. At the periphery, the blood supply comes from periosteal arteries.

The physis is avascular, receiving oxygen and nutrients from epiphyseal and metaphyseal vessels. Small branches from the epiphyseal arteries pass through the resting zone and terminate at the top of the proliferative zone. On the metaphyseal side, the interosseous artery and metaphyseal arteries combine and form loops that penetrate into the zone of calcification and the hypertrophic zone, bringing nutrition to osteoprogenitor cells producing bone in the cartilage matrix scaffold (Siffert 1966; Robertson 1990; Kember 1960; Fujii et al. 2000; Brighton 1984, 1978; Bisgard 1933; Nicholson and Nixon 1961; Trueta 1957).

At the periphery of the physis (the periphysis), the zone of Ranvier is responsible for the horizontal growth of the physis and the perichondrial ring (ring of Lacroix) provides mechanical stability to the physis (Shapiro et al. 1977). In the proximal femur, the perichondrial fibrocartilaginous complex replaces the zone of Ranvier and the ring of Lacroix (Chung et al. 1976). Branches from a periosteal artery supply the zone of Ranvier (Figure 16).

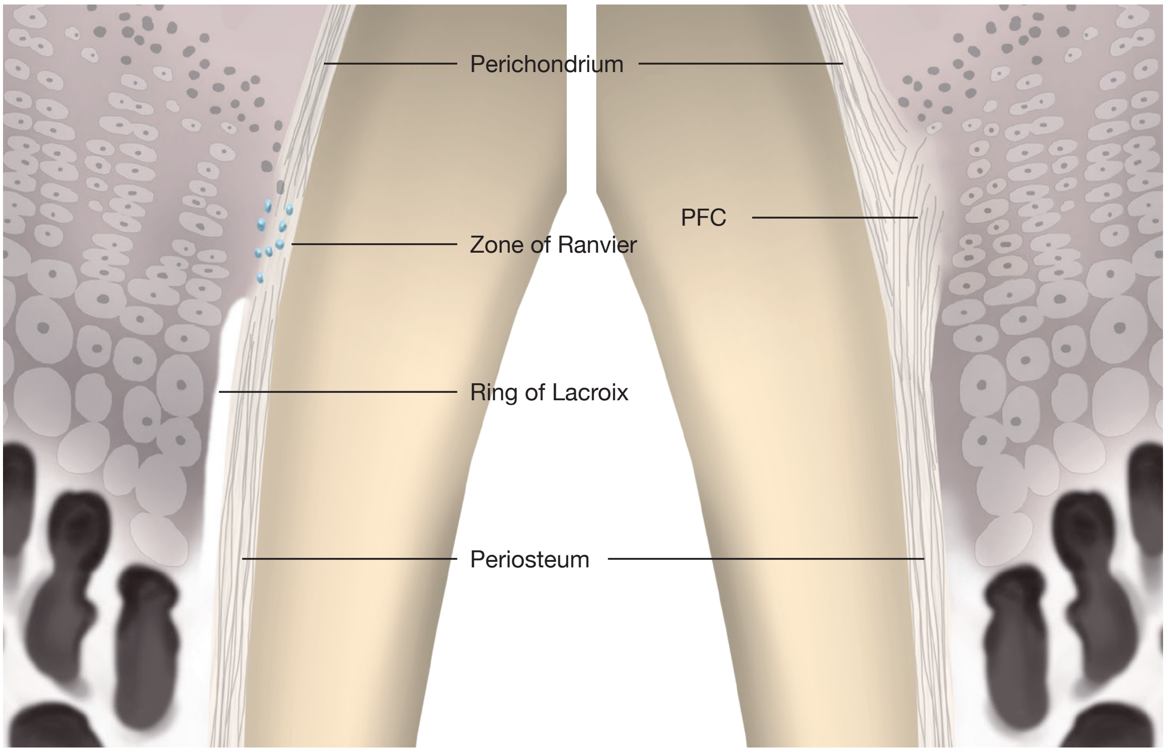

Figure 16 In the proximal femur, the Zone of Ranvier and Ring of Lacroix are replaced by the perichondrial fibrocartilaginous complex (PFC).

1. 2. 3. The proximal femur

The previously described fundamentals of bone growth and physeal anatomy apply to the proximal femur with certain modifications.

At birth, the cartilaginous epiphysis forms the femoral head and greater trochanter that have the same shape as in an adult. The epiphysis is supported by a curved physis. With physeal growth, the epiphysis divides into the femoral head epiphysis and the greater trochanter apophysis (Figure 17). Concurrently, the proximal femoral physis is extracapsular at birth but intracapsular in adolescence (Morgan and Somerville 1960; Ogden 1974).

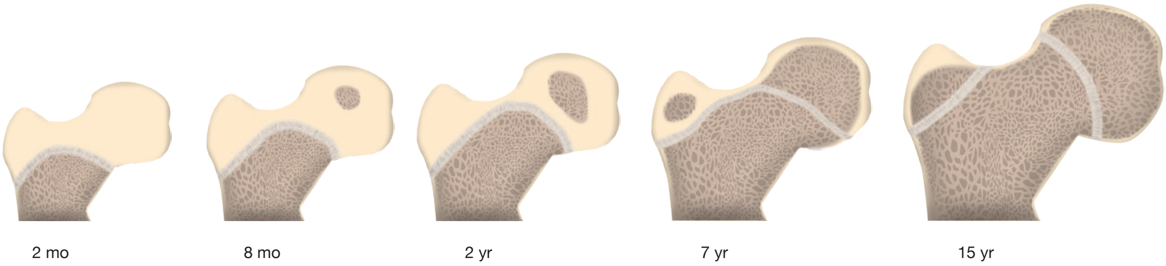

Figure 17 At birth, the cartilaginous epiphysis forms the femoral head and greater trochanter. With physeal growth, the epiphysis divides into the femoral head epiphysis and the greater trochanter apophysis and the physis moves from being extracapsular at birth to intracapsular in adolescence.

Blood supply to the proximal femoral physis changes during growth. Arteries in the ligamentum teres supplement the epiphyseal blood supply but only during the first three to four years. During growth, the anterior half of the physis receives blood from the lateral circumflex artery and the posterior half from the medial circumflex artery. Eventually, the blood supply to the femoral head is received from branches of the medial circumflex artery. The postero-inferior artery supplies the inferior portion of the femoral head, while the postero-superior artery travels in the intertrochanteric groove and supplies the superior portion of the femoral head. Both arteries traverse the physis superficially, leaving them vulnerable to damage if the femoral neck or physis is fractured (Figure 18). Even though the proximal femoral physis is one of the least injured long-bone physes, the vulnerable blood supply leads to a high complication rate when injuries occur (Wertheimer and Lopes Sde 1971; Tucker 1949; Dias and Lamont 1989; Chung 1976; Ogden 1974; Trueta 1957).

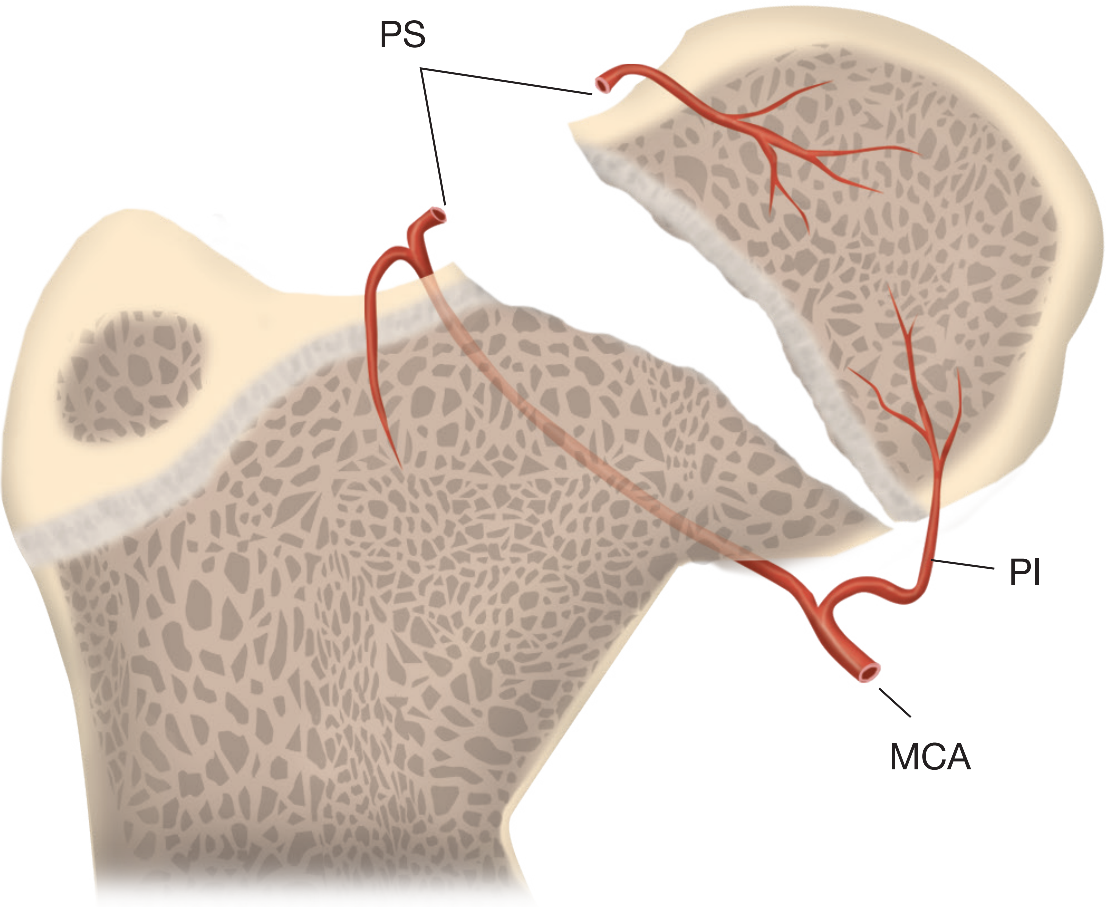

Figure 18 Eventually, the blood supply to the femoral head is received from the posteroinferior (PI) and the posterosuperior (PS) branches of the medial circumflex artery (MCA). Both arteries traverse the physis superficially, leaving them vulnerable to damage if the femoral neck or physis is fractured.

Closure of the proximal femoral physis begins supero-laterally and continues infero-medially. Complete closure occurs in half of 14-year-old females and 17-year-old males (Flecker 1942; Dvonch and Bunch 1983).

The microscopic anatomy of the proximal femoral physis differs slightly from what is seen in other physes, with the zone of Ranvier and ring of Lacroix replaced by the perichondrial fibrocartilaginous complex (Chung et al. 1976). The presence of a bony peg on the underside of the epiphysis projecting down into a socket on the metaphysis has also been described. In the literature, it is referred to as the epiphyseal tubercle and it is believed to be an important stabiliser of the epiphysis (Liu et al. 2013; Tayton 2007, 2009) (Figure 19).

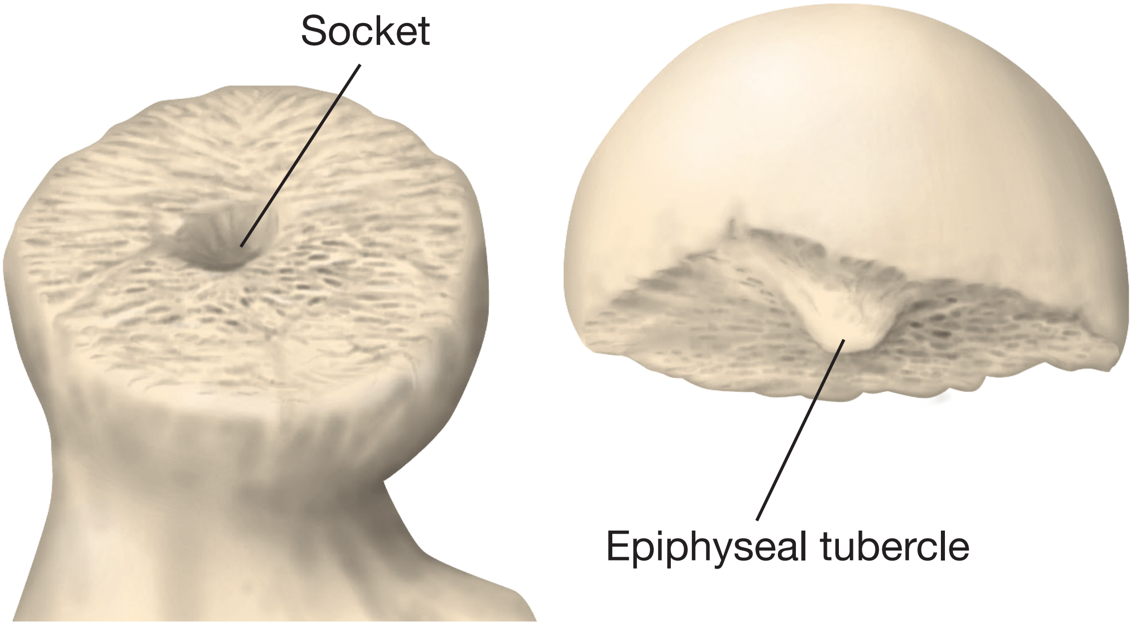

Figure 19 The epiphyseal tubercle projects down into a socket on the metaphysis.

1. 2. 4. Factors affecting bone growth

The mechanisms controlling physeal growth are not well known. Factors known to influence physeal growth can be divided into general factors, which can affect many or all physes, and local factors, affecting only a single physis. Genes, nutrition, hormones and general health are examples of general factors. Local factors include blood supply, mechanical forces, traumatic injuries and infection.

Mechanical forces

A certain physiological load is needed for normal bone growth (Malina 1969). The effect of load on bone growth can be summarised in two laws.

Heuter-Volkmann's Law establishes that physeal growth is retarded by increased load and accelerated by decreased load. This leads to the physis aligning itself perpendicularly to the force applied and usually at a right angle to the longitudinal axis of the bone (Heuter C 1862).

Wolff's Law proposes that the bone in a healthy individual will adapt to the loads under which it is placed. Under increased load, the bone becomes stronger and thicker through appositional growth, while a reduced load leads to weakening of the bone. A fracture of a long bone that heals at an angle therefore has a tendency to straighten when a load is applied because of increased appositional bone growth on the concave side of the fracture (Wolff J 1986).

Blood supply disturbance

Compromised blood supply disturbs physeal growth, but the way this happens depends on the supply route that is affected.

If the blood supply from the metaphyseal side is compromised, the vascular loops stop invading the hypertrophic zone and the cells in the hypertrophic zone accumulate. The cells in the resting and proliferating zone receive blood supply from the epiphyseal vessels and continue to grow. Longitudinal growth therefore continues and the physis widens in the affected area.

In the event of a diminished blood supply through the epiphyseal vessels, cells in the resting and proliferating zones are deprived of oxygen and nutrients. Longitudinal growth ceases in the affected area, but the vascular loops continue invading the hypertrophic zone and the physis narrows. If only a part of the physis is affected, the rest of the physis continues to grow and angular deformities occur (Trueta and Trias 1961; Trueta and Morgan 1960; Trueta and Little 1960; Trueta and Amato 1960; Jaramillo et al. 1993) (Figure 20).

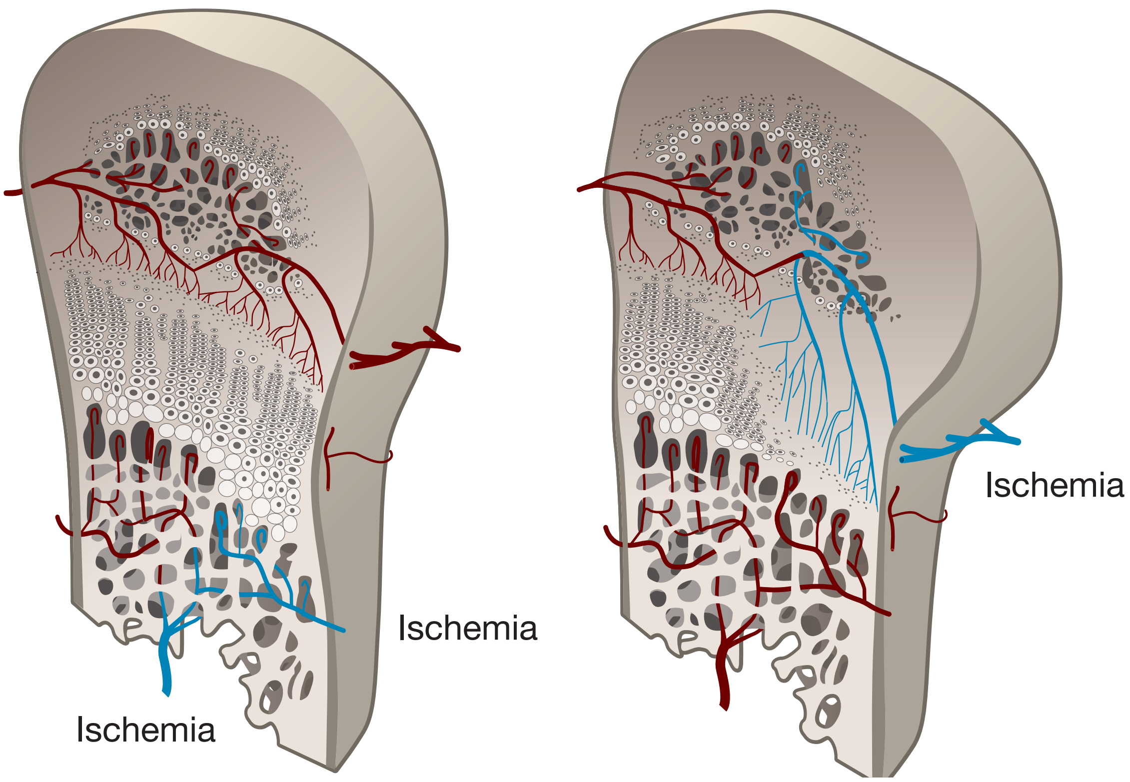

Figure 20 A compromised blood supply on the metaphyseal side causes the continued growth and widening of the physis, but growth cessation and narrowing of the physis occurs if the blood supply is compromised on the epiphyseal side.

Trauma

Fractures in and around the physis affect growth, most probably through changes in blood flow. Hefti et al. (Hefti et al. 1991) described four types of growth disturbance following fractures in children (Table 1).

Table 1 The four types of growth disturbance seen following fractures in children according to Hefti et al.

Type 1	Increased growth in the whole physis
Type 2	Decreased growth in the whole physis or complete growth arrest
Type 3	Increased growth in part of the physis, creating angular deformation
Type 4	Asymmetrical growth arrest, with the formation of a bone bridge

The exact reason why overgrowth of the physis occurs following a fracture is unclear. One possible explanation is the increase in blood flow following healing of the fracture.

Physiolysis or fracture/physiolysis or avulsion most often leads to diminished growth or, in the worst case, complete growth cessation. If the injury is confined to the cellular columns or hypertrophic zone of the physis and the epiphyseal blood supply is intact, normal growth usually resumes.

Infection

Growth disturbances due to infections are due either to the direct destruction of the physis or, secondarily, to disturbed blood supply.

1. 3. BIOMECHANICAL STUDIES

Animal models are often appropriate and are commonly used to investigate phenomena that are impossible to investigate by other means (Pearce et al. 2007). In recent years, many experimental biomechanical studies and studies of paediatric orthopaedics of the hip and spine have used porcine models (Table 2).

Table 2 Examples of biomechanical studies using a porcine model, the research question and results

STUDY	MODEL STUDIED	RESEARCH QUESTION	RESULTS
Baranto et al. 2005	Spine	The strength of the immature porcine spine against compressive load in flexion and extension	The growth zone was the weakest part of the porcine spine against all forms of load. Most extensive injuries were seen after loading in extension.
Baranto et al. 2005	Spine	The strength of the immature porcine spine against compressive load after induced disc degeneration	The growth zone and, to a lesser extent, the endplate were the weakest parts of the porcine spine. Degenerative discs appeared to withstand higher compressive loads than non-degenerative discs.
Karlsson et al. 2008	Spine	The strength of the immature porcine spine against compressive load	The growth plate was the weakest part of the growing porcine spine.
Thoreson et al. 2010	Spine	The effect of repetitive loading on the compressive strength of the young porcine spine	No difference in compressive strength was found after repetitive loading.
Kaigle et al. 1998	Spine	The stiffness of the porcine intervertebral discs during load in the intact state, after injury and in the degenerative state	The stiffness of the vertebral discs increases with heavier loads, repeated loading and/or disc degeneration.
Lundin et al. 2000	Spine	The difference in injury patterns between the mature and immature porcine spine after failure loading	In the immature spine, a fracture was consistently found in the endplate through the posterior part of the growth zone, displacing the annulus fibrosus with a bony fragment at the point of insertion to the vertebra. In the mature spines, there was a fracture of the vertebra in four cases and, in two cases, a rupture of the annulus fibrosus without a bony fragment.

STUDY	MODEL STUDIED	RESEARCH QUESTION	RESULTS
Dodds et al. 2008	Hip	The iatrogenic damage caused by a procedure where the ligamentum teres was reconstructed in porcine hips	The procedure did not result in avascular necrosis of the femoral head, osseous bar formation across the proximal femoral physis, proximal femoral metaphyseal growth disturbance, chondrolysis, or disturbance in normal acetabular development.
Wenger et al. 2007	Hip	The biomechanical properties of the ligamentum teres	The ultimate load on the ligamentum teres in the porcine hip was similar to those reported for the human anterior cruciate ligament. The strength of the ligamentum teres may confirm its potential for providing early stability in childhood hip reconstructions.
Hosalkar et al. 2011	Hip	The pressure inside the porcine hip when placed in different positions	Position significantly altered pressures, with the lowest values in neutral and the highest in hyperextension.
Kishan et al. 2006	Hip	The stability of different screw fixation of an unstable slipped capital femoral epiphysis	Slipped capital femoral epiphysis stabilisation with two screws leads to increased stability compared with a single screw fixation.
Upasani et al. 2006	Hip	The effect of screw thread distribution on the stability of screw fixation of an unstable slipped capital femoral epiphysis	Too few threads in the epiphysis, as well as too few in the metaphysis, lead to reduced stability.
Pawaskar et al. 2011	Hip	Validated a finite element methodology for modelling hemiarthroplasty of the hip using a porcine model	Due to fairly good agreement in predicted and measured values of contact stresses and contact areas, the integrated methodology that was developed can be used as a basis for future work.

1. 3. 1. Anatomy and biomechanics of the porcine hip

Two morphological types of hip joint can be used to describe almost all mammalian hip joints. The coxa recta is a hip with an aspherical femoral head. The head is shifted antero-inferiorly on a short, broad femoral neck. The coxa rotunda, on the other hand, is a hip with a round femoral head on a relatively long and narrow femoral neck. Most mammals have coxa recta, which gives a sturdy hip joint, most ideal for running, hopping and jumping but with restricted abduction and rotational movement. Coxa rotunda is found primarily in swimmers and large climbers and permits a larger range of rotational movement but less power because of unnecessary rotation and abduction, requiring stabilising muscle action during jumping and high-speed running (Hogervorst et al. 2011). The variations between coxa recta and coxa rotunda exist on a continuum. As in most quadrupeds, the characteristics of porcine hip morphology are predominantly of the coxa recta type, while coxa rotunda characteristics predominate in the human hip (Figure 21).

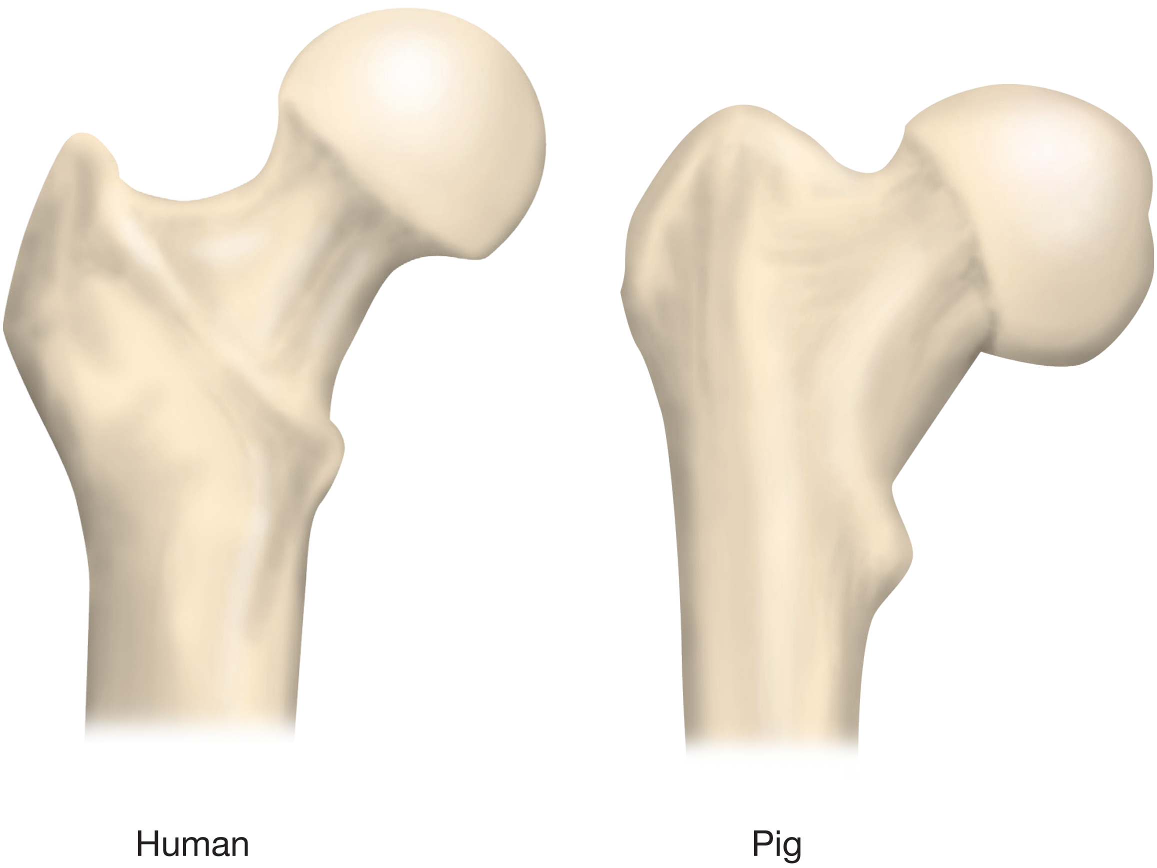

Figure 21 The porcine proximal femur has a shorter and broader femoral neck and the femoral head is aspherical, as compared to the human proximal femur.

The proximal femoral epiphyses of one-year-old pigs are similar in size to those in the adolescent human and the shear strength is comparable, which makes the porcine hip model ideal for research on hip biomechanics and different disorders of the hip (Chung et al. 1976; Ipsen et al. 2002).

Little knowledge exists when it comes to porcine hip biomechanics and comparisons with human hip biomechanics are therefore difficult. The hip biomechanics of other quadrupeds have been investigated and similarities to human hip biomechanics are present, especially in terms of load and forces on the femoral head (Bergmann et al. 1999; Bergmann et al. 1984).

1. 4. PATIENT-REPORTED OUTCOME MEASURES

When measuring the outcomes of different treatments and procedures, there are basically two approaches; objective measurements, such as ROM, muscle strength and different functional tests or changes on radiological images. This can be said to be the clinician's point of view. The patient's point of view can be assessed with subjective measurements, most often in the form of questionnaires or interviews. Interviews are time consuming and the results are open to interpretation and bias. They are, on the other hand, helpful in developing questionnaires, which are more practical for clinical research.

Both objective and subjective approaches give valuable information to the clinician but with certain limitations. Both approaches are open to measurement error and subjective measurements are open to bias. Subjective and functional phenomena are difficult to measure with objective measurements and vice versa. Objective phenomena can be measured as length in metres, weight in grams or force in Newtons. Measuring pain, on the other hand, is best done subjectively using a visual analogue scale (VAS), for example.

Even though objective measurements are helpful, a good objective outcome does not equate with a good subjective outcome. The patient's range of motion may have increased, but his pain may have increased. So, when measuring the outcome of different treatments and procedures, both a subjective and an objective measurement should be used.

For objective and subjective measurements, it is important to choose the right instrument. The instrument that is best for objective measurements is usually obvious. Good examples are a set of scales for weight, a goniometer for ROM and a length meter for distance. Finding a suitable instrument for subjective measurements, on the other hand, is not as straightforward. An instrument developed for children may not be suitable for adults, an instrument for women may be unsuitable for men, an instrument for the French my be unsuitable for the English and an instrument for athletes may be unsuitable for non-athletes.

The instrument that is used must therefore be developed or validated for the intended patient group. The instrument must also be developed or validated for the condition in question. An instrument developed for patients with shoulder pathology may not be suitable for patients with hip pathology and an instrument developed for patients with osteoarthritis of the knee may not be suitable for patients with a traumatic meniscal rupture. It is therefore important to choose an instrument with both the study population and the condition in mind.

Even if an instrument is developed for the intended condition and patient group, its psychometric quality cannot be guaranteed. Every instrument must therefore be validated and tested for reliability.

In recent years, health-related patient-reported outcome measures (HR-PROMs) have been used increasingly to evaluate the effectiveness of treatment or to compare different interventions in clinical trials. These are questionnaires completed by patients to measure perceptions of their general health or their health in relation to a specific illness or condition. The questions, or items, relate to different characteristics, or constructs (e.g. symptom, function or quality of life), of the condition. One-dimensional HR-PROs measure only one construct, while multidimensional HR-PROs measure two or more constructs. Multidimensional HR-PROMs are essentially different questionnaires combined into one and the results for each construct should be reported separately, as a subscale, for example.

1. 4. 1. Psychometric properties and COSMIN

Every HR-PRO used in clinical research should be validated and tested for reliability. Otherwise, the scientific value of the research can be questioned. Until recently, researchers had not come to any agreement about which psychometric properties to look for in an HR-PRO, their terminology or definitions. The Consensus-based Standards for the selection of health Measurement Instruments (COSMIN) study was an international Delphi study, where 80 experts from the fields of psychology, epidemiology, statistics and clinical medicine gathered to come to an agreement on these matters (Mokkink et al. 2010a, b). The measurement properties were divided into three different domains; validity, reliability and responsiveness. Certain measurement properties were further divided into aspects of that particular measurement property.

Figure 22 shows the relationship between the different measurement properties and table 3 shows the definitions of the domains, measurement properties and aspects of the measurement properties.

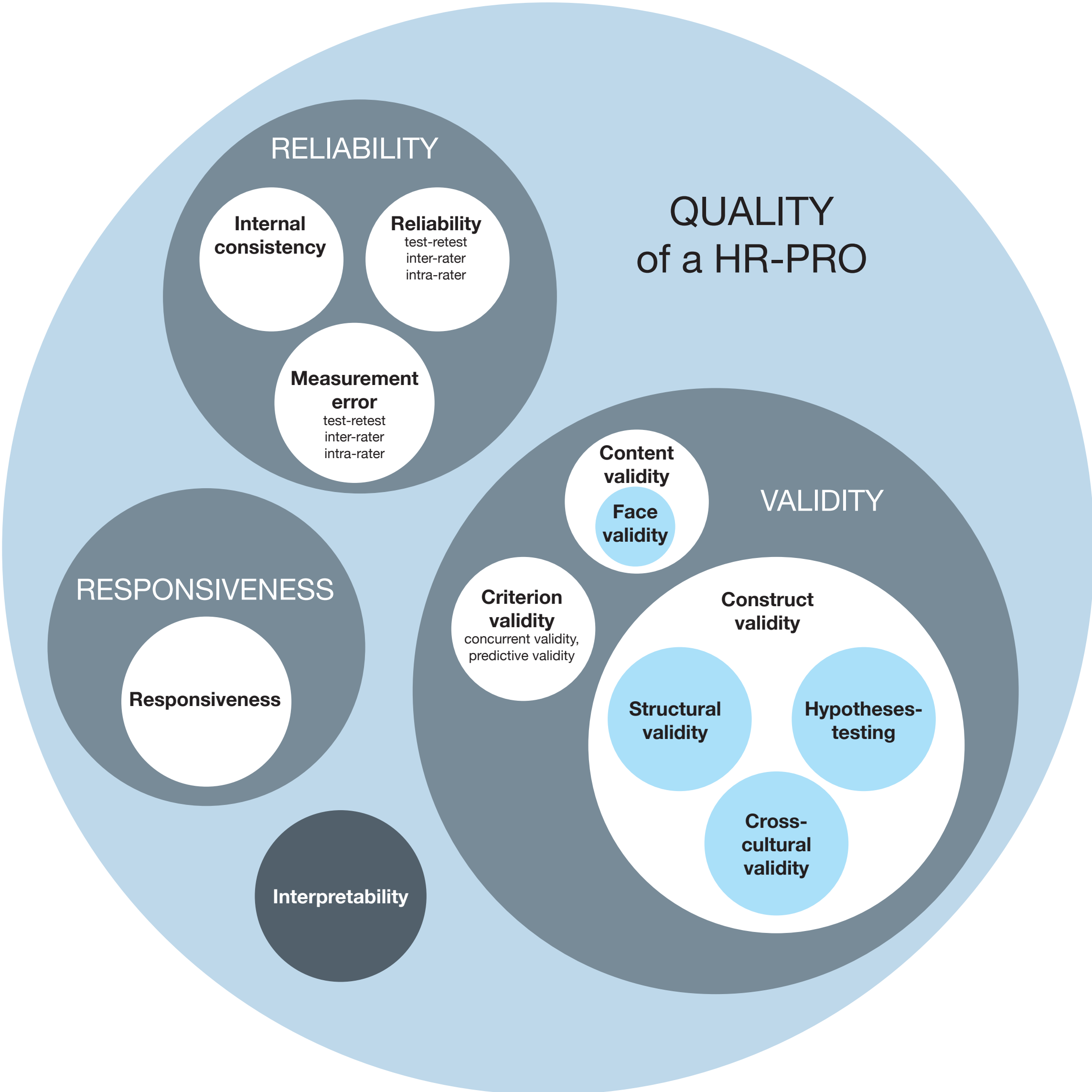

Figure 22 (Adapted from the COSMIN checklist manual)
The COSMIN taxonomy. Three quality domains (reliability, validity and responsiveness) are distinguished, each containing one or more measurement properties. Although interpretability is not regarded as a measurement property, it is an important characteristic of a measurement instrument.

Table 3 COSMIN definitions of domains, measurement properties and aspects of measurement properties (adapted from the COSMIN manual)

	TERM		DEFINITION
Domain	Measure-ment property	Aspect of a measurement property	
Reliability			The degree to which the measurement is free from measurement error
	Internal consistency		The degree of the interrelatedness among the items
	Reliability		The proportion of the total variance in the measurements which is due to 'true'* differences between patients
	Measurement error		The systematic and random error of a patient's score that is not attributed to true changes in the construct to be measured
Validity			The degree to which an HR-PRO instrument measures the construct(s) it purports to measure
	Content validity		The degree to which the content of an HR-PRO instrument is an adequate reflection of the construct to be measured
		Face validity	The degree to which (the items of) an HR-PRO instrument indeed look as though they are an adequate reflection of the construct to be measure
	Construct validity		The degree to which the scores of an HR-PRO instrument are consistent with hypotheses (for instance, with regard to internal relationships, relationships to scores of other instruments, or differences between relevant groups), based on the assumption that the HR-PRO instrument validly measures the construct to be measured
		Structural validity	The degree to which the scores of an HR-PRO instrument are an adequate reflection of the dimensionality of the construct to be measured
		Hypothesis testing	Idem construct validity
		Cross-cultural validity	The degree to which the performance of the items on a translated or culturally adapted HR-PRO instrument are an adequate reflection of the performance of the items of the original version of the HR-PRO instrument

		Criterion validity	The degree to which the scores of an HR-PRO instrument are an adequate reflection of a 'gold standard'
Responsiveness			The ability of an HR-PRO instrument to detect change over time in the construct to be measured
	Responsiveness		Idem responsiveness
Interpretability**			Interpretability is the degree to which qualitative meaning – that is, clinical or commonly understood connotations – can be assigned to the quantitative scores or change in scores of an instrument

*The word 'true' must be seen in the context of the CTT, which states that any observation is composed of two components – a true score and error associated with the observation. 'True' is the average score that would be obtained if the scale were given an infinite number of times. It refers only to the consistency of the score and not to its accuracy.

**Interpretability is not regarded as a measurement property but as an important characteristic of a measurement instrument.

During the development of the COSMIN manual, consensus on which statistical methods to use when evaluating the different measurement properties was reached to a certain extent.

1. 4. 2. iHOT, HAGOS and other scores used

A number of different patient-reported outcome scores are currently in use for patients undergoing hip arthroscopy and patients with hip and groin disorders (Kemp et al. 2013; Thorborg et al. 2010; Tijssen et al. 2011) (Table 4).

Table 4 Patient-reported outcome measures currently in use for patients undergoing hip arthroscopy

SCORE	TYPE	NUMBER OF ITEMS	DOMAINS	DEVELOPED FOR PATIENT GROUP
HHS (Harris 1969)	Likert scale, a single total score is calculated.	10	Four (pain, function, range of movement and absence of deformity)	Traumatic arthritis after hip dislocation and acetabular fractures
mHHS (Byrd and Jones 2000)	Likert scale, a single total score is calculated.	8	Three (pain, function and ADL	From the HHS, for young to middle-aged patients undergoing hip arthroscopy
HOOS (Nilsdotter et al. 2003)	Likert scale, a total score is calculated for each of five subscales	40	Five (pain, symptoms, ADL, sport/recreation function, hip-related QOL.	Middle-aged and elderly patients with hip OA
HOS (Martin et al. 2006)	Likert scale, a total score is calculated for each of two subscales	28	Two (ADL and sports)	Young and middle-aged patients undergoing hip arthroscopy
HAGOS (Thorborg et al. 2011b)	Likert scale, a total score is calculated for each of six subscales	37	Six (pain, symptoms, physical function in daily living, physical function in sport and recreation, participation in physical activities and hip-related QOL	Young and middle-aged adult patients with hip and/or groin pain
iHOT33 (Mohtadi et al. 2012)	VAS scale, a single total score is calculated	33	Four (symptoms and functional limitation, sports and recreational activities, job-related concerns and social, emotional and lifestyle concerns)	Young and middle-aged, active patients with hip disorders
iHOT12 (Griffin et al. 2012)	VAS scale, a single total score is calculated	12	Four (symptoms and functional limitation, sports and recreational activities, job-related concerns and social, emotional and lifestyle concerns)	From the iHOT33, for young and middle-aged, active patients with hip disorders

HR-PROMs developed for other patient groups, such as the HHS, are burdened by unacceptable ceiling effects in younger and healthier patients (Wamper et al. 2010) and its modified version, the mHHS, is limited in correlating good score outcome with patient satisfaction (Aprato et al. 2012). The reliablity and content validity of the mHHS and the HOS have also been questioned (Hinman et al. 2013; Kemp et al. 2013). The HOOS was developed for patients with OA and has been shown to have good psychometric properties in this group and even among patients undergoing hip arthroscopy (Thorborg et al. 2010; Kemp et al. 2013). In a recent systematic review, Harris-Hayes et al. recommended the HAGOS and the iHOT33 for use in young and middle-aged, active patients suffering from FAI (Harris-Hayes et al. 2013).

The HAGOS published in 2011 was developed and tested according to the COSMIN checklist for young and middle-aged patients with hip and groin pain (Thorborg et al. 2011b). It was later translated and adapted to Swedish (Thomeé et al. 2013). The HAGOS comprises 37 items in six subscales; symptoms (7 items), pain (10 items), function in daily living (5 items), function in sport and recreation (8 items), participation in physical activities (2 items) and hip- and/or groin-related quality of life (5 items). Each item is answered on a five-level Likert scale and produces a score from 0 (best) to 4 (worst). The total score for each subscale is calculated as the sum of the items included and transformed to a score from 0 (worst) to 100 (best). No aggregated score is calculated.

Another HR-PRO, the international Hip Outcome Tool 12 (iHOT12), was published in 2012 (Griffin et al. 2012). The iHOT12 was developed from the longer iHOT33 (Mohtadi et al. 2012) and included 12 items of 33 from the iHOT33. The patient answers each item by marking a VAS between two anchor statements. Each item gives a score between 0 (worst) and 100 (best) and a total score is calculated as a simple mean from all item scores. The iHOT12 is intended to be easier to use in routine clinical practice, as the iHOT33 is most likely to be used in a research setting. They were developed for young active patients with hip disease undergoing hip arthroscopy.

Neither the iHOT33 nor the iHOT12 was developed according to the COSMIN checklist, but the Swedish version of the iHOT12 has been evaluated in accordance with the COSMIN checklist (Jónasson et al. 2013).

(For a full version of the scores, see the appendix.)

The EQ-5D is a standardised, generic HR-PRO intended for use as a measurement of general health outcome (EuroQol 1990). It is applicable to a variety of conditions and different treatments and delivers a simple profile and index value for health status. It measures five constructs (mobility, self-care, usual activities, pain/discomfort and anxiety/depression) on three levels (no problems, some problems, major problems) (the 3L version) or five levels (no problems, slight problems, moderate problems, severe problems and extreme problems) (the 5L version). The scores range from -0.594 to 1, with 1 representing full health (and values lower than 0 considered as worse than death). The patient also records his/her self-rated health on a 20 cm vertical VAS marked from 0 to 100, with 0 equalling the worst health imaginable and 100 the best health imaginable. The result from the VAS recording is reported separately.

When evaluating the outcome of treatments, the subjective symptoms patients experience tell only half the story. The patient's activity level affects his/her well-being and the symptoms he/she experiences. It is therefore important to report the activity levels of patients so that a fair comparison between patient groups can be made. The Tegner activity scale grades activity based on work and sports activities (Tegner and Lysholm 1985). The Hip Sports Activity Scale (HSAS) is a similar scale focusing on hip-related activity and sports and was published in 2013 (Naal et al. 2013).

1. 4. 3. Translation and cultural adaptation

International and multicultural research projects are common and, with today's globalisation, international co-operation is increasing. When designing these projects, the need for a common outcome measurement is indisputable. Comparing outcomes between studies performed in different countries is also easier when the same measurements are used. There is a constant need to translate and adapt different outcome measurements between languages and cultures. For the essence and properties of the outcome measurements to be applicable in another language and/or culture, the translation and adaptation should be performed in a standardised manner.
Guillemin et al. (Guillemin et al. 1993) proposed a certain methodology and published guidelines for the cross-cultural adaptation of HR-PROs. This work was later refined by Beaton et al. (Beaton et al. 2000). The guidelines serve as a template for the translation and cultural adaptation of HR-PROs.

Páll Sigurgeir Jónasson

2

AIMS

AIMS

2. AIMS

In recent years, evidence of a causal relationship between high-impact training and the subsequent development of osteoarthritis of the hip has increased. FAI has been proposed as a plausible link between high-impact training and the development of osteoarthritis in athletes. Although the cam deformity can develop in young athletes' hips in relation to high-intensity training and competition, the exact mechanism of its development is unknown.

Hip joint arthroscopy has become a common procedure for the treatment of FAI and other hip disorders. It is important to evaluate the outcome of treatment in a standardised manner to be able to compare the results of different treatments. This will help diminish controversy surrounding new treatment options and aid clinicians in deciding which treatment is best for their patient.

There is a lack of patient-reported outcome measures for the young and active patient presenting with hip symptoms. The outcome measures currently used have been developed for an older, less active patient with osteoarthritis of the hip.

2. 1. The specific aims of this thesis are:

• Compare the morphological characteristics of the hips and range of movement between a group of elite athletes (football and ice-hockey players) and a group of non-athletes.

• Investigate the link between the morphological characteristics of the hips and findings on clinical examination.

• In a biomechanical study, develop a model in which porcine hips can be loaded cyclically and to failure from different loading directions. Then use this model to examine whether and which type of damage occurs in the proximal porcine femur during loading.

• Translate and adapt patient-reported outcome measures for young and active patients with hip symptoms to Swedish and validate the translations for future use in this patient group.

Páll Sigurgeir Jónasson

3

PATIENTS & METHODS

PATIENTS & METHODS

3. 1. STUDY I

3. 1. 1. Subjects

A group of 40 elite athletes from the local ice-hockey team and the local football team were invited to take part in the present study. Both teams play in the highest league in Sweden in their respective sports. Players born and raised outside Scandinavia were excluded, as were players that had undergone an operation on either hip.

The control group was recruited through flyers at Gothenburg University. The inclusion criteria for the control group were male gender, 18-40 years of age and not participating in any organised sports or elite level sports before or at present. Participants who had undergone previous surgery on either hip were also excluded.

All participants received oral and written information relating to the study in advance and signed written consent forms before entering the study.

3. 1. 2. Clinical examination

All subjects were examined in the supine position by the first author. Hip flexibility, internal and external rotation in 90° flexion, was measured using a goniometer. A hip impingement test was performed with 90° flexion, adduction and internal rotation (FADDIR). It was registered as positive if the subject reported pain during the performance of the test. A FABER (flexion, abduction, external rotation) test was performed by placing the lateral malleoli of the examined side above the patella of the contralateral knee. The hip was then abducted until full ROM or until the subject reported pain. During examination, care was taken to keep the pelvis stable so the registered movement only occurred in the hip joint. A positive hip impingement test and pain on FABER test was registered. Moreover, the angle between the lower leg and the examination table on the FABER test was measured using a goniometer.

3. 1. 3. Radiographic examination

Radiological measurements and investigations were performed using plain radiographs of both hips with the Osirix software (Pixmeo, Geneva, Switzerland). All subjects underwent standardised AP of both hips and pelvis, together with Lauenstein-view radiographs.

The alpha angle was measured according to Nötzli et al. (Notzli et al. 2002) and the beta angle according to Brunner et al. (Brunner et al. 2010) on all radiographs. The anterior offset and anterior offset ratio were measured on the Lauenstein-view radiographs as described by Tannast et al. (Tannast et al. 2007). Superior offset was measured in the same way on the AP hip and pelvis radiographs. The centre-edge (CE) angle was measured on the AP pelvic view by measuring the angle between a vertical line and a line drawn from the centre of the femoral head to the lateral border of the acetabulum. A cross-over sign (a line drawn along the anterior margin of the acetabulum crosses a line drawn along the posterior margin of the acetabulum), (Reynolds et al. 1999), an ischial spine sign (the ischial spine projects medially from the pelvic brim towards the pelvic inlet) (Kalberer et al. 2008) and a posterior wall sign (the posterior margin of the acetabulum lies medially to the centre of the femoral head), (Reynolds et al. 1999) were registered if present. The acetabular depth was classified on the AP pelvic view as protrusio (the femoral head contacts the ilio-ischial line), profunda (the acetabular fovea contacts the ilio-ischial line) or normal.

The femoral head-neck junction was classified according to Agricola et al. as a normal, flat or prominent head-neck junction (Agricola et al. 2014) on the Lauenstein view.

The presence of osteoarthritis was defined according to the Tönnis classification (Table 5).

Table 5 The Tönnis classification system of osteoarthritis by radiographic changes

GRADE	RADIOGRAPHIC CHANGES
0	Normal
1	Sclerosis, osteophytes and/or slight narrowing of the joint space
2	Small cysts, moderate joint space narrowing
3	Large cysts, severe narrowing or obliteration of the joint space

3. 2. BIOMECHANICAL STUDIES II AND III

3. 2. 1. Experimental animals

A total of 25 proximal femurs from 13 young (5 months), male, domestic pigs, with a median weight of 90 kg (range 85-95), were obtained from the local abattoir. The specimens were dissected and cleaned of soft tissue, muscle and capsular attachments. The diameter of the femoral heads was measured in the coronal and sagittal planes with a measurement error of less than 1 mm using a slide calliper (Kosashvili et al. 2008).

3. 2. 2. Mechanical test procedures

Nine femurs were used in pilot tests of the model in order to establish a correct fixation method; the remaining sixteen femurs were used for the studies. In Study 2, nine femurs were used for the mechanical testing procedures. In Study 3, six femurs were used for the mechanical testing procedures, while one acted as an untested control but was otherwise treated in exactly the same way.

The prepared proximal femurs were fixed with Plastic PaddingTM (Loctite Technology) in a metal fixture and attached to the actuator of a servo-hydraulic universal testing machine (MTS Test Star, Minneapolis, MN, USA). A custom-made aluminium rod with a small plastic cup (25 mm in diameter), contoured to the shape of the femoral head, was attached to the upper crosshead of the testing machine. The physeal line was clearly visible on the surface of the femoral head and was used as a guide for the placement of the plastic cup, which was proximal to the line.

In Study 2, the proximal femurs were loaded to failure in one of three directions. Three femurs were loaded from the lateral side in the coronal plane, three femurs were loaded from the anterior side in the sagittal plane and three femurs were loaded vertically (Figures 23-25). On those loaded from the lateral side, the major trochanter was removed to facilitate access for the loading rod with the plastic cup.

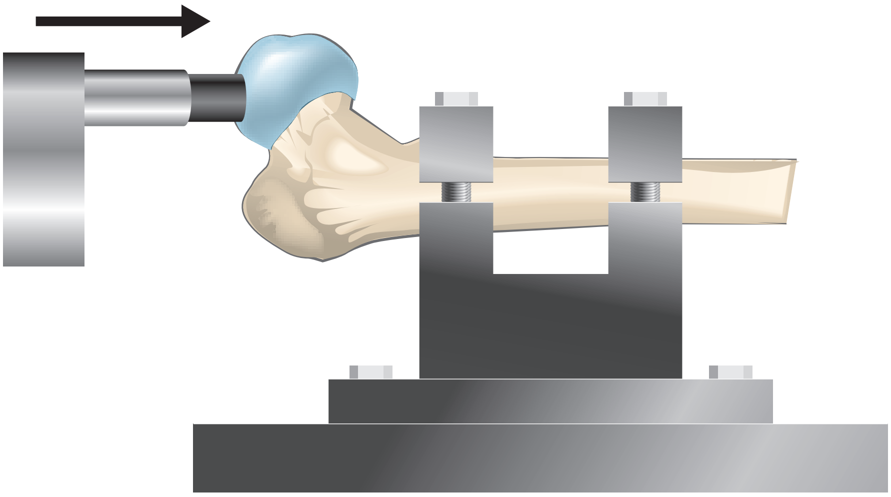

Figure 23 Set-up for vertical loading of the specimens.

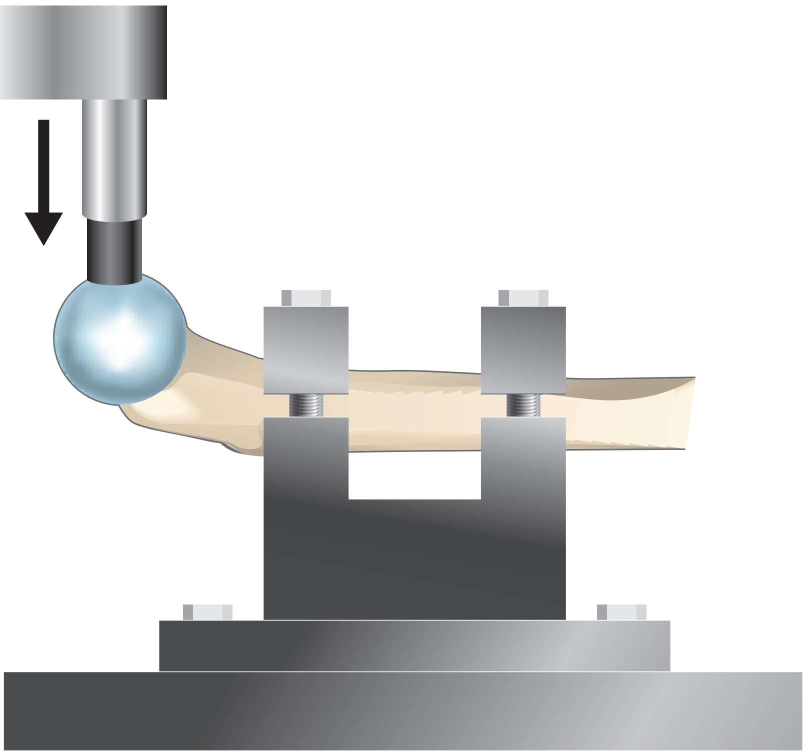

Figure 24 Set-up for anterior loading of the specimens.

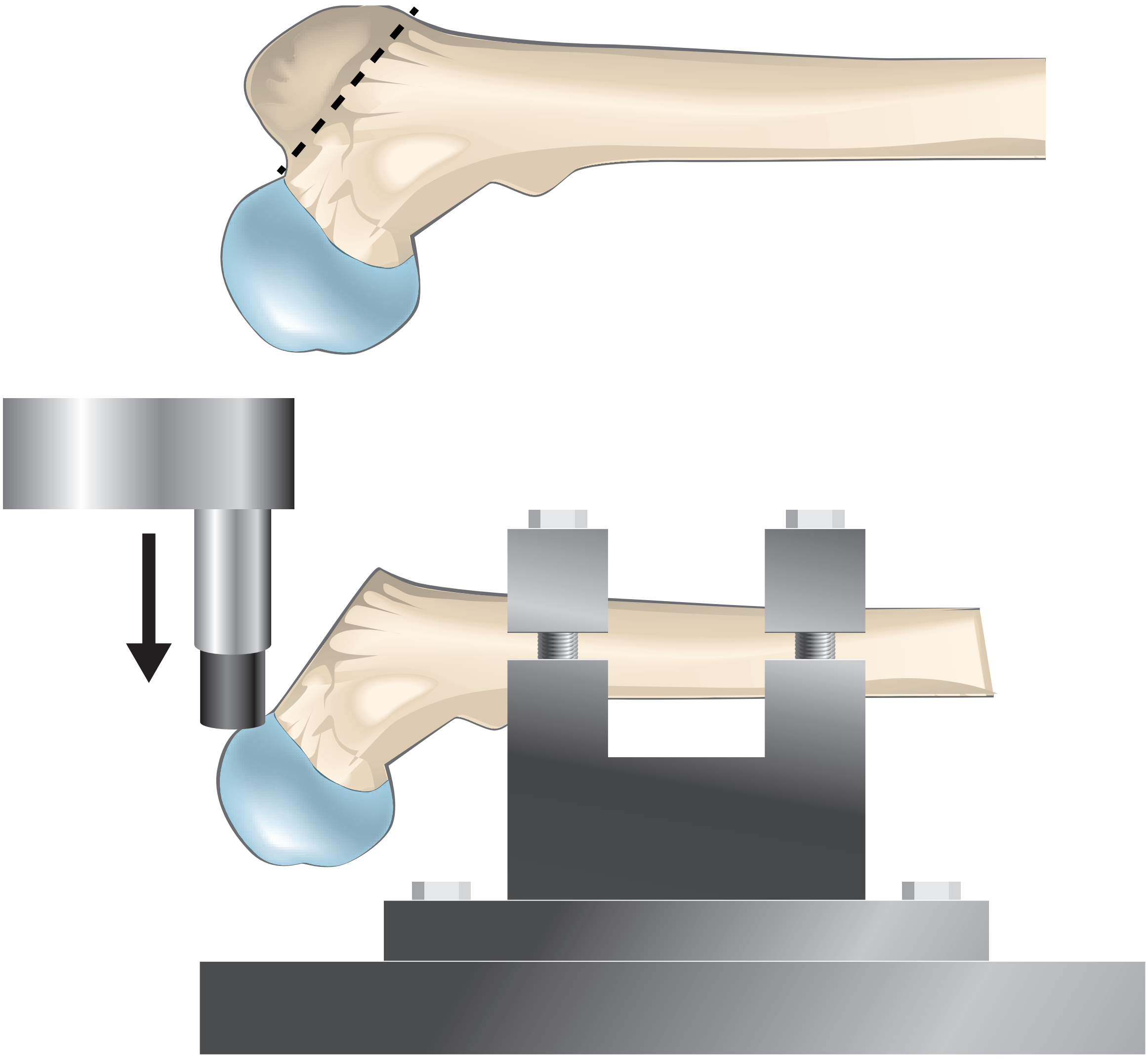

Figure 25 Set-up for lateral loading of the specimens.The greater trochanter was removed to facilitate access of the loading ram.

The deformation control mode was set at a rate of 0.05 mm/sec. Force and deformation were recorded continuously and failure was defined as a sudden decrease in force, which could be seen on the force/deformation diagram on the computer. Moreover, the failure was visual and audible to the researchers (the first and second authors) in all test cases. Loading was stopped immediately after the first sign of failure.

In Study 3, the femurs were loaded repetitively at 2 Hz for 50,000 cycles. Three femurs (labelled 1-3) were loaded vertically with 2,500 N (Figure 23) and three femurs (labelled 4-6) were loaded with 2,000N antero-superiorly (Figure 26), simulating 45° of hip flexion.

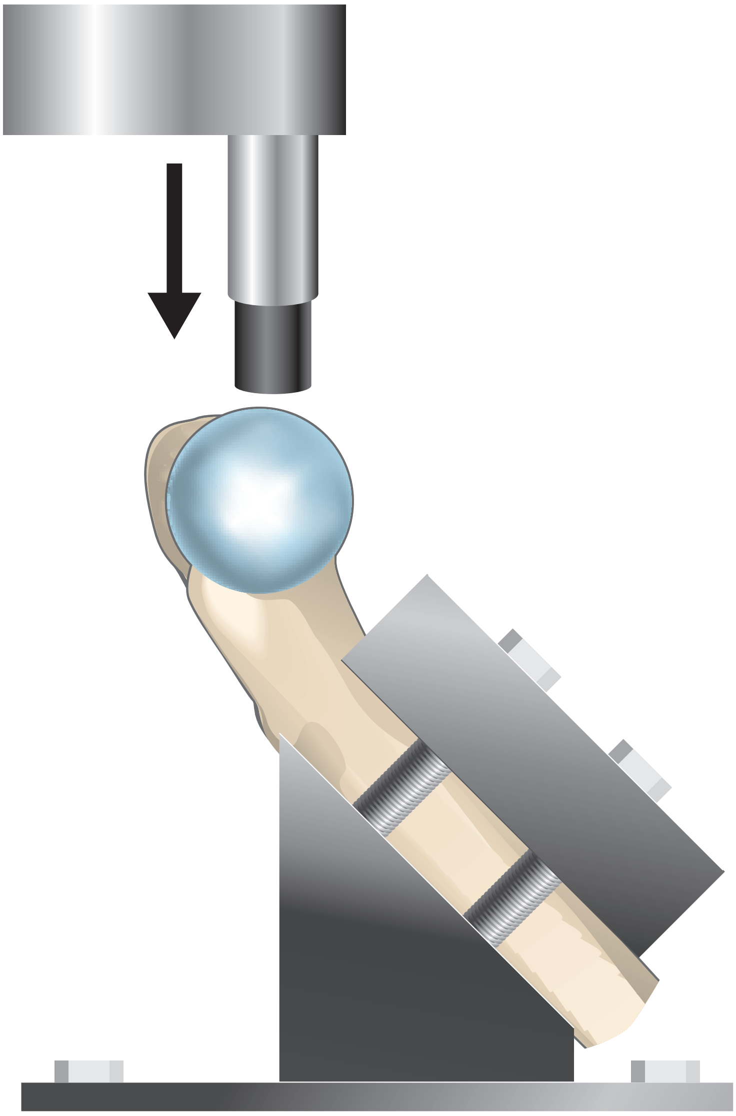

Figure 26 Set-up for antero-superior loading of the specimens, simulating 45° of flexion.

3. 2. 3. Macroscopic and histological examinations

After loading, the sizes of the footprint left by the plastic cup on the femoral head and its distance from the physeal plate were measured. Any signs of physeolysis or fracture, visual or palpable, were registered, if present.

The specimens were then stored in a -20°C freezer until completely frozen. When frozen, they were sawn into four equally thick primary slices in the loading plane using a bandsaw. The slices were decalcified, dehydrated, fixed in paraffin and cut in 4 μm slices using a microtome. Four slices from each specimen were then stained with hematoxylin-eosin and alcian blue solution and examined microscopically for injuries.

Study 2: In Study 2, the histological presence of epiphyseolysis, the percentage of the epiphyseal plate that was damaged, the epiphyseal zone that was damaged and a Salter-Harris classification were registered for each slice (Figure 27). The integrity of the PFC and the presence of the epiphyseal tubercle were also noted and registered.

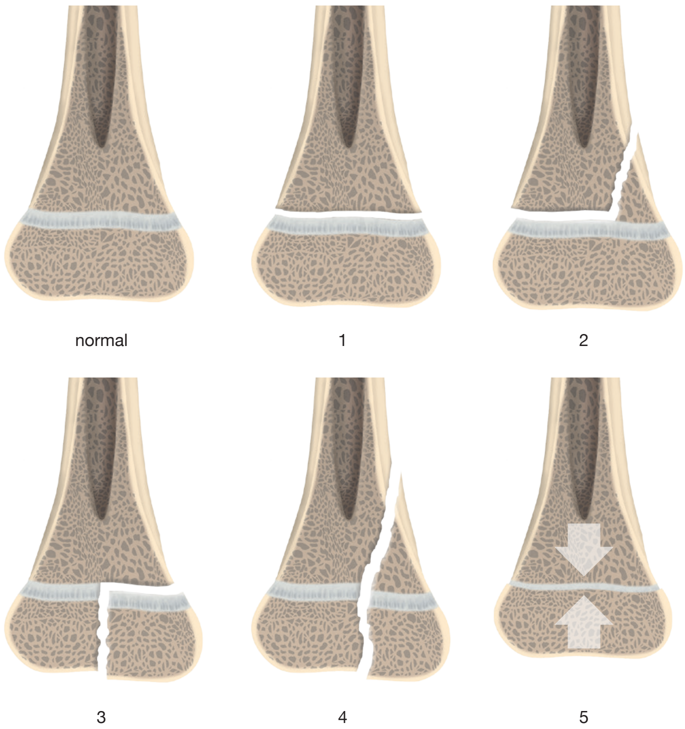

Figure 27 The Salter-Harris classification of physeal fractures. 1: Transverse fracture through the epiphyseal plate. 2: Fracture through the epiphyseal plate and metaphysis. 3: Fracture through the epiphyseal plate and metaphysis. 4: Fracture through the epiphyseal plate and both the epi- and metaphysis. 5: A compression fracture of the epiphyseal plate.

Study 3: In Study 3, the histological presence of damage to the physeal plate or adjacent bone was registered for each slice.

3. 2. 4. Magnetic resonance imaging (MRI)

In Study 3, MRI was performed on all specimens directly after loading and also on the control femur, in a Philips Achieva 3.0TM (Philips Healthcare Inc.) using a wrist protocol, an extremity coil and SPAIR sequences. The MRI from each specimen was compared with the control and the difference in signal intensity was registered in eight different zones (Figure 28), medially and laterally to the epiphyseal tubercle in the epiphysis and the metaphysis and adjacent to the physeal plate, above and below.

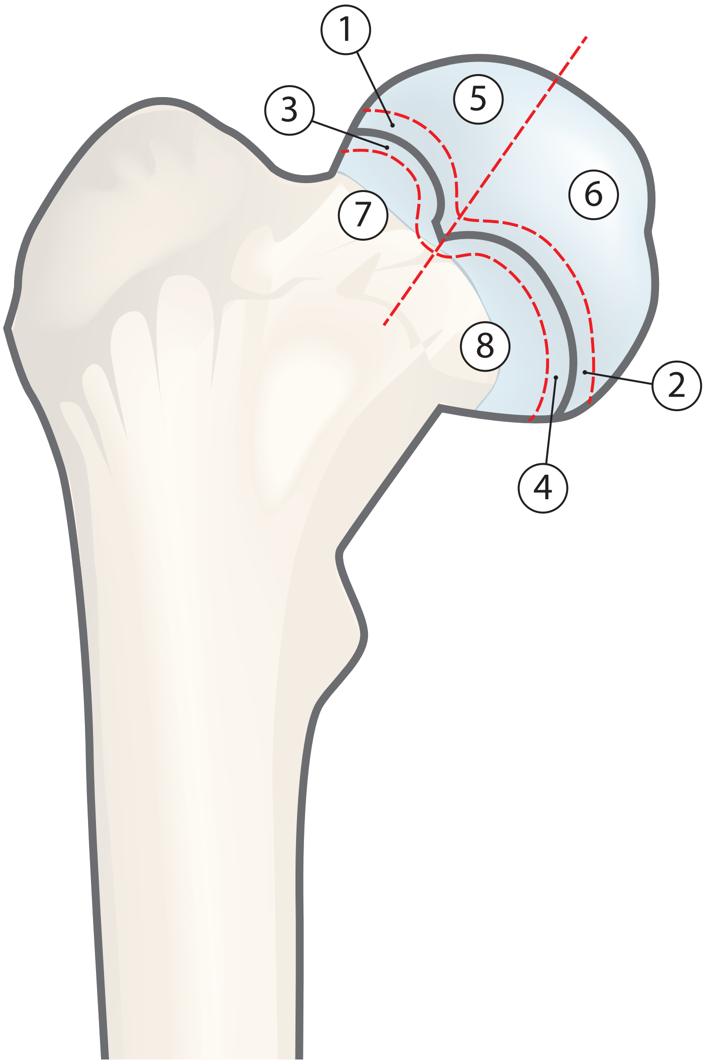

Figure 28 The different zones compared on the MRI of the control with the MRI of the loaded specimens. 1= Superior and adjacent to the physeal line, laterally to the epiphyseal tubercle. 2= Superior and adjacent to the physeal line, medially to the epiphyseal tubercle. 3= Inferior and adjacent to the physeal line, laterally to the epiphyseal tubercle. 4= Inferior and adjacent to the physeal line, medially to the epiphyseal tubercle. 5= Epiphysis, laterally to the epiphyseal tubercle. 6= Epiphysis, medially to the epiphyseal tubercle. 7= Metaphysis, laterally to the epiphyseal tubercle. 8= Metaphysis, medially to the epiphyseal tubercle.

3. 3. PATIENT-REPORTED OUTCOME MEASURES, STUDIES IV AND V

3. 3. 1. Translation and adaptation

The adaptation of the iHOT12 and HAGOS to Swedish was performed in several steps, as proposed by Beaton et al. (Beaton et al. 2000). The guidelines describe a five-step process, where different translators translate the HR-PRO to the target language. The translations are then synthesized into one version to be translated back into the original language. The back-translation is reviewed by an expert committee that, by consensus, creates a pre-final version that is consequently tested in a clinical study.

The original versions of the iHOT12 and HAGOS were translated into Swedish by three of the authors (two orthopaedic surgeons and one physiotherapist) who are fluent in Swedish and are well acquainted with the English and Danish languages. All three are experienced in working with patients with hip and groin disability. The three translations were then synthesised into a Swedish version by an expert panel of three orthopaedic surgeons and one physiotherapist. The synthesised version, the result of consensus among the panel members, was back-translated into the original language by a native English-speaking person and the translation was subsequently compared with the original version by the same panel. Minor differences between the original and back-translated version were resolved by consensus among the panel members.

A pilot test to check the acceptability and, to a certain extent, face validity of the synthesised version was performed on 10 healthy individuals without any history of hip or groin problems. They were encouraged to make comments with their answers. This was done to ensure that the questions would not be experienced as obtrusive and that non-health-care professionals would be able to understand the questions. After the pilot test, minor modifications were made to the synthesised translation, according to consensus among the panel members, mainly replacing the professional words with more lay terms. Content validity, the degree to which the instrument adequately reflects the measured construct (Mokkink et al. 2009), was deemed acceptable, according to consensus among the expert panel members.

3. 3. 2. Subjects

The reliability, validity and responsiveness of the final versions, the iHOT12-S and HAGOS-S, were assessed according to the COSMIN checklist (Mokkink et al. 2010a) in a clinical study. Five hundred and two patients, requiring hip arthroscopy for FAI, completed the questionnaire on their first visit to an experienced hip surgeon. FAI was diagnosed on a clinical examination and on radiographs. The patients repeated the questionnaires four months post-operatively. At the time of the study, 256 and 360 of the 502 patients had post-operatively completed the iHOT12-S and HAGOS-S respectively. A group of 23 and 26 patients completed the iHOT12-S and HAGOS-S respectively, pre-operatively, on two separate occasions within three weeks for test–retest reliability measurements.

All patients evaluated their overall hip function on a global perceived effect (GPE) VAS from 0 (extremely poor function) to 100 (perfect function). A change of 20 points or more on the GPE scale was considered to represent a clinically relevant change in patient symptoms (Gallagher et al. 2001; Emshoff et al. 2011; Kelly 2001). To be included in the test–retest evaluation, the patients' condition had to be regarded as clinically stable during this period. It was therefore decided a priori that only patients with a change of fewer than 20 points between test and retest on the VAS could be included in this analysis. The GPE scale was also used for evaluations of responsiveness.

The patients completed the Swedish versions of the EQ-5D (Herdman et al. 2011) and correlations between the EQ-5D, the HAGOS-S and the iHOT12-S calculated for construct validity. Their physical activity level was assessed with a Swedish version of the Hip Sports Activity Scale (HSAS) (Naal et al. 2013). The patients were also asked to use the HSAS to estimate their physical activity level when they were teenagers and before their symptom debut.

3. 4. STATISTICAL ANALYSIS

Statistical analysis was performed using the Statistical Package for the Social Sciences (SPSS) (version 20, 2010 SPSS Inc., Chicago, Illinois, USA).

3. 4. 1. Study I

Range of motion and radiological measurements (angles and distances) between groups were compared with the independent Student t test. Pearson's correlation coefficient was used to quantify the association between range of motion and radiological measurements. The chi-square test or Fisher's exact test was used for categorical variables. P-values of < 0.05 were considered significant. To evaluate the differences in Agricola grade and numerical values, one-way analysis of variance (ANOVA) was performed. If the ANOVA showed statistical significance, a post-hoc (Bonferroni) test was used to evaluate differences between each subgroup.

3. 4. 2. Studies II and III

No statistical analyses were relevant for these studies due to their study design.

3. 4. 3. Studies IV and V

Most data were ordinal, so non-parametric statistics were used. The level of significance was set at $p < 0.05$. The questionnaires were web based, leaving the patients no option but to answer all the questions. As a result, no individual items were missing.

Reliability

The reliability of an HR-PRO is the degree to which it is free from measurement error (Mokkink et al. 2009). To evaluate the reliability of an HR-PRO, its internal consistency, test-retest reliability and measurement error must be assessed.

Internal consistency is the degree of interrelatedness between the items (Mokkink et al. 2009). Internal consistency was measured for the six subscales of the HAGOS-S and the whole iHOT12-S from the baseline values and was deemed good if Cronbach's alpha was between 0.70 and 0.95 (Terwee et al. 2007).

Test-retest reliability is defined as the proportion of the total variance in the measurements which is due to true differences between patients (Mokkink et al. 2009). The Intraclass Correlation Coefficient (ICC), (3.1 two-way mixed effects model absolute agreement) was calculated for each subscale of the HAGOS-S and for each of the 12 items separately and for the total average score of the iHOT12-S. An ICC of > 0.70 was deemed acceptable (Terwee et al. 2007). Wilcoxon's paired test was performed to assess whether there were significant differences in scores between the test occasions.

Measurement error is the systematic and random error of the score, not attributed to the construct that is being measured (Mokkink et al. 2009). Measurement error was expressed as the standard error of the mean (SEM), using the formula $SD \times \sqrt{1 - ICC}$, with SD as the standard deviation in scores from all patients at baseline (Weir 2005). The smallest detectable change (SDC), a change in a score that exceeds the measurement error, was calculated at individual level as $SEM \times 1.96 \times \sqrt{2}$ and at group level as $SEM \times 1.96 \times \sqrt{2} / \sqrt{n}$ (Busija et al. 2008).

Validity

Construct validity is the degree to which the scores of an HR-PRO instrument are consistent with a priori hypotheses, based on the assumption that the instrument validly measures the construct that is going to be measured (Mokkink et al. 2009). A principal component factor analysis, with varimax rotation and the eigenvalue set at > 1.0, was performed to assess the structural validity of each iHOT12-S item and HAGOS-S subscales. Hypothesis testing was performed using Spearman's correlation coefficient for non-parametric data, comparing the scores from the iHOT12-S, HAGOS-S and the EQ-5D scores.

A priori hypotheses were formulated. With the iHOT12 and HAGOS developed for similar patient groups and measuring essentially the same constructs, we expected high correlations (Spearman r>0.50) between the iHOT12-S average score and all the subscales of the HAGOS-S. Moderate correlations were expected (Spearman r>0.30) between the subscales of the HAGOS-S and the total average score of the iHOT12-S with all subscales of the EQ-5D, but higher correlations were expected with the mobility, usual activities and pain/discomfort subscales on the EQ-5D than with the self-care and anxiety/ depression subscales.

Responsiveness

The responsiveness of an HR-PRO instrument is its ability to detect changes over time (Mokkink et al. 2009) – in the present study, between pre-operative status and a four-month follow-up. In our experience, most patients have recovered well at three to four months post-operatively and a four-month follow-up was therefore selected for the responsiveness calculations. Responsiveness was assessed by Spearman's correlation coefficient, standardised response mean (SRM) and effect size (ES). Correlations between the GPE and the total average score of the iHOT12-S and each HAGOS-S subscale were measured. Patients completed the questionnaire at the four-month follow up. The SRM was calculated as the mean change in score divided by the SD of the change. The ES was calculated as the mean change in score divided by the SD of the baseline score (Streiner and Norman 2008). The patients were divided into three groups: those reporting worsening of hip function between pre-operatively and the four-month follow-up (at least 20 points lower GPE score), those that reported no change in function (0-19 points higher or lower GPE score) and those that reported improved function (at least 20 points higher GPE score).

A priori hypotheses were formulated for responsiveness. It was hypothesised that the change in the score for the HAGOS-S subscales and iHOT12-S individual items would correlate with the GPE scale with a Spearman correlation coefficient of > 0.3. It was, moreover, hypothesised that the SRM and ES would be higher for those reporting an improvement in hip function between pre-operatively and the four-month follow-up (at least 20 points higher GPE score) and lower for those reporting a worsening of hip function between pre-operatively and the four-month follow-up (at least 20 points lower GPE score).

Interpretability

Interpretability is defined as the degree to which it is possible to assign qualitative meaning to the quantitative scores of an instrument or a change in scores (Mokkink et al. 2009). It includes the distribution of total scores and change scores, floor and ceiling effects and an estimation of the minimal important change (MIC) and/or minimal important difference (MID). Floor and ceiling effects were defined as being present if more than 15% of patients reported lowest (0) or highest (100) possible scores (Thorborg et al. 2011). The MIC was calculated as 0.5 x SD both at baseline and at four months (Norman et al. 2003).

Páll Sigurgeir Jónasson

4

SUMMARY OF PAPERS

SUMMARY OF PAPERS

4. 1. STUDY I

The morphological characteristics and range of motion in the hips of athletes and non-athletes

Introduction

The cam deformity of the head-neck junction of the proximal femur causes FAI. FAI is a common cause of hip and groin pain and reduced range of motion and impaired performance in athletes. The aetiology of the cam deformity is unknown, but there is growing evidence that it may lead to osteoarthritis of the hip. Evidence has emerged, supporting mechanical factors such as vigorous training, affecting the proximal femoral physis, as a cause of the development of cam deformity. The aim of this study was to compare the morphological and radiological characteristics and range of motion of the hip in elite athletes and non-athletes.

Methods

Seventeen football players and 15 ice-hockey players were examined clinically and radiographically. Thirty non-athletes were used as a control group and examined in the same manner. Hip range of motion was measured and the FADDIR and FABER tests were performed. Plain radiographs of both hips and pelvis were acquired including a modified Lauenstein view. The centre-edge angle, alpha angle, beta angle, caput-collum-diaphysis angle, head-neck offset and Tönnis grade were registered.

Results

The athletes had a significantly higher Tönnis grade (right P=0.009, left P=0.004), more pain on the FADDIR test (right P=0.006, left P=0.001) and a significantly lower ROM in internal (right P=0.003, left P=0.025) and external rotation (P<0.001). There was no significant difference in alpha angle measurements between the groups. When a cam deformity was placed superiorly on the head-neck junction, as measured with the alpha angle on an AP pelvis view, a correlation was shown with lower external rotation (right P=0.001, left P=0.004) and low-grade osteoarthritis (Tönnis grade 1), (P=0.015, left P=0.020), while a more anteriorly placed cam deformity, as measured with the alpha angle on a Lauenstein view, was correlated with significantly reduced internal rotation (right P=0.029, left P=0.013). There were significant correlations between the alpha angle and head-neck offset measurements (P<0.001-0.020).

Conclusion

The reduced range of motion and pain on the FADDIR test among the athletes can be caused to a certain extent by the higher occurrence of osteoarthritis in that group. The alpha angles in the control group were higher than previously reported. In the presence of a cam deformity, the high load imposed on the elite athlete's hip can accelerate the development of osteoarthritis, especially if the deformity is located superiorly on the head-neck junction of the proximal femur.

Table 1 Range of movement in degrees between the groups on clinical examination. Mean (standard deviation; SD) values.

	ATHLETES N=30	CONTROLS N=30	P-VALUE
Flexion right	106.9 (8.8)	111.4 (8.0)	0.044
Flexion left	108.1 (8.5)	111.0 (7.2)	n.s.
Internal rotation right	19.7 (12.1)	0.003	
Internal rotation left	17.3 (10.6)	0.025	
External rotation right	50.5 (18.5)	<0.001	
External rotation left	51.3 (17.9)	<0.001	
Faber right	23.0 (17.9)	16.3 (12.7)	n.s.
Faber left	22.5 (17.2)	14.4 (11.3)	0.035

Table 2 Pain on FADDIR and FABER tests.

		ATHLETES N=30	CONTROLS N=30	P-VALUE
FADDIR	Right	9	1	0.006
	Left	11	1	0.001
FABER	Right	5	0	0.026
	Left	4	1	n.s.

Table 3a Radiological measurements in degrees and millimetres on the pelvis AP. Mean (standard deviation; SD) values.

		ATHLETES N=28	(SD)	CON-TROLSN=30	(SD)	P-VALUE
Centre-edge angle	Right	32.0	(6.6)	33.2	(5.4)	n.s.
	Left	31.8	(7.4)	33.5	(5.6)	n.s.
Caput-collum-diaphysis angle	Right	129.0	(4.0)	127.1	(5.0)	n.s.
	Left	127.7	(3.0)	126.7	(4.5)	n.s.
Alpha angle	Right	58.1	(15.2)	53.7	(13.7)	n.s.
	Left	55.9	(13.8)	52.8	(13.1)	n.s.
Beta angle	Right	41.8	(18.2)	46.0	(15.1)	n.s.
	Left	43.2	(16.2)	46.8	(15.1)	n.s.
Head neck offset (mm)	Right	6.6	(4.6)	7.4	(3.9)	n.s.
	Left	8.2	(5.0)	8.1	(3.8)	n.s.
Caput diameter (mm)	Right	66.5	(2.9)	63.0	(3.0)	<0.001
	Left	66.1	(3.0)	62.7	(2.6)	<0.001

Table 3b Radiological measurements in degrees and millimetres on the Lauenstein projection. Mean (standard deviation; SD) values.

		ATHLETES N=28	(SD)	CON-TROLS N=30	(SD)	P-VALUE
Alpha angle	Right	62.0	(12.9)	62.5	(12.0)	n.s.
	Left	57.9	(11.5)	57.0	(12.0)	n.s.
Beta angle	Right	37.8	(17.0)	43.9	(15.7)	n.s.
	Left	41.3	(15.4)	50.0	(14.6)	0.040
Head-neck offset (mm)	Right	4.9	(3.6)	4.3	(3.2)	n.s.
	Left	5.9	(3.9)	5.3	(3.8)	n.s.
Caput diameter (mm)	Right	67.0	(3.7)	64.5	(2.8)	0.005
	Left	67.2	(3.5)	64.9	(3.2)	0.011

Table 4 Osteoarthritic (OA) changes in the different groups as classified with the Tönnis grade.

	RIGHT HIP		LEFT HIP	
	NO OA	OA	NO OA	OA
Athletes N=28	12	16	11	17
Controls N=30	23	7	23	7
P-value	0.009		0.004	

Table 5 Radiological signs of acetabular retroversion and presence of coxa profunda.

		ATHLETES N=28	CONTROLS N=30	P-VALUE
Cross-over sign	Right	15	21	n.s.
	Left	15	24	0.032
Ischial spine sign	Right	15	22	n.s.
	Left	17	24	n.s.
Posterior wall sign	Right	13	17	n.s.
	Left	16	19	n.s.
Coxa profunda	Right	0	10	0.001
	Left	0	7	0.006

Table 6 Differences in ROM in degrees between individuals with osteoarthritis as classsified on the Tönnis grade and individuals without arthritic changes.

		NO ARTHRITIS N=34		ARTHRITIS N=22		
		MEAN	(SD)	MEAN	(SD)	P VALUE
Flexion	Right	111.5	(8.8)	105.4	(8.1)	0.012
	Left	109.9	(7.4)	109.4	(9.4)	n.s.
Internal rotation	Right	17.2	(11.9)	12.6	(10.7)	n.s.
	Left	15.1	(11.1)	14.3	(11.2)	n.s.
External rotation	Right	43.8	(17.6)	37.7	(17.6)	n.s.
	Left	45.9	(16.9)	39.1	(18.1)	n.s.
FABER	Right	17.4	(13.5)	23.5	(18.7)	n.s.
	Left	15.9	(10.6)	21.5	(20.3)	n.s.
SD=standard deviation						

Table 7 Differences in radiographic measurements between individuals with osteoarthritis as classified on the Tönnis grade and individuals without osteoarthritic changes.

		NO ARTHRITIS N=35 RIGHT 34 LEFT		ARTHRITIS N=23 RIGHT 24 LEFT		
		MEAN	SD	MEAN	SD	P VALUE
Centre-edge angle	Right	31.7	(6.5)	34.0	(4.8)	n.s.
	Left	32.9	(6.6)	32.3	(6.5)	n.s.
Caput-collum-diaphysis angle	Right	127.8	(3.9)	128.3	(5.6)	n.s.
	Left	127.8	(4.0)	126.4	(3.6)	n.s.
Alpha angle	Right	52.1	(12.5)	61.5	(15.8)	0.021
	Left	49.8	(9.3)	60.7	(15.8)	0.004
Beta angle	Right	48.8	(15.1)	36.5	(16.4)	0.005
	Left	51.1	(12.5)	36.4	(15.7)	<0.001
Superior head-neck offset	Right	8.0	(3.9)	5.3	(4.3)	0.015
	Left	9.2	(3.6)	6.4	(4.9)	0.020
Femoral head diameter	Right	63.9	(3.6)	65.8	(2.7)	0.037
	Left	63.6	(3.3)	65.5	(2.8)	0.020
Alpha angle Lauenstein view	Right	61.4	(12.1)	63.5	(12.9)	n.s.
	Left	55.8	(11.0)	59.8	(12.4)	n.s.
Beta angle Lauenstein view	Right	43.7	(14.9)	36.7	(18.1)	n.s.
	Left	49.4	(13.2)	40.8	(17.2)	0.036
Anterior head-neck offset	Right	4.7	(3.4)	4.4	(3.5)	n.s.
	Left	5.8	(3.7)	5.4	(4.0)	n.s.

4. 2. STUDY II

Strength of the porcine proximal femoral epiphyseal plate: the effect of different loading directions and the role of the perichondrial fibrocartilaginous complex and epiphyseal tubercle – an experimental biomechanical study

Introduction
The musculoskeletal system in adolescent athletes is often subjected to high, non-physiological loads. This is known to cause morphological and degenerative changes in bone, joints and intervertebral discs. It has been suggested that the cam deformity of the proximal femoral head-neck junction can be a result of a growth disturbance or injury in the proximal femoral physeal plate caused by non-physiological loading during adolescence. Two structures, the epiphyseal tubercle (ET) and the perichondrial fibrocartilaginous complex (PFC), have been proposed as stabilisers of the proximal femoral epiphysis. The aim of this study was to develop an experimental biomechanical model to evaluate the strength of the porcine proximal femoral epiphysis in different loading directions and, furthermore, to investigate the stabilising role of the PFC and ET.

Methods
A biomechanical model was developed, where the porcine proximal femur was fixed and loaded in different directions. Nine young (5 months old) porcine proximal femurs were loaded to failure; three in the anterior-posterior direction, three in the lateral-medial direction and three in the vertical direction. The injured proximal femurs were examined both macroscopically and histologically.

Results
The specimens loaded in the antero-posterior direction failed at a median load of 1,750N (range 1,679-1,756). On histological examination, total epiphyselysis was seen on one specimen and a subtotal epiphyseolysis in two specimens. The specimens loaded in the latero-medial directions failed at a median load of 920N (range 918-1,148). Histological examination revealed a subtotal epiphyseolysis in all specimens. On macroscopic examination, in the specimens loaded in the antero-posterior and latero-medial directions, a small cleavage was seen laterally over the physeal line, but no movement could be detected between the injured parts.

The vertically loaded specimens failed at a median load of 7,397N (range 7,008-7,413). On histological examination, a Salter-Harris type 2 fracture epiphyseolysis was seen in all specimens (Figure 29). Macroscopically, a cleavage laterally over the physeal line and a fracture on the medial collum were seen. On palpation, movement over the fracture was easily detected.

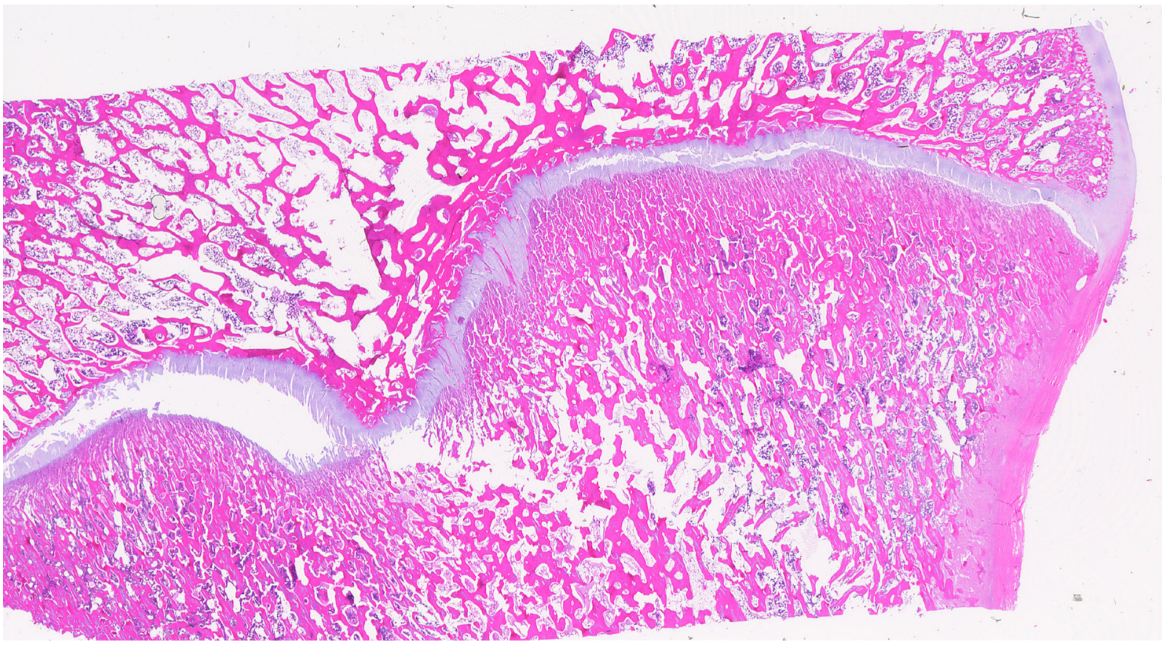

Figure 29 Showing a type 2 Salter-Harris epiphyseal plate fracture, with the bone injury originating from the epiphyseal tubercle.

The PFC was usually intact in the antero-posteriorly loaded specimens, but it was damaged on the latero-medially loaded specimens (Figure 30). The epiphyseal tubercle was seen pressing against its metaphyseal socket in the latero-medially loaded specimens (Figure 31). The fracture in the vertically loaded specimens originated from the epiphyseal tubercle.

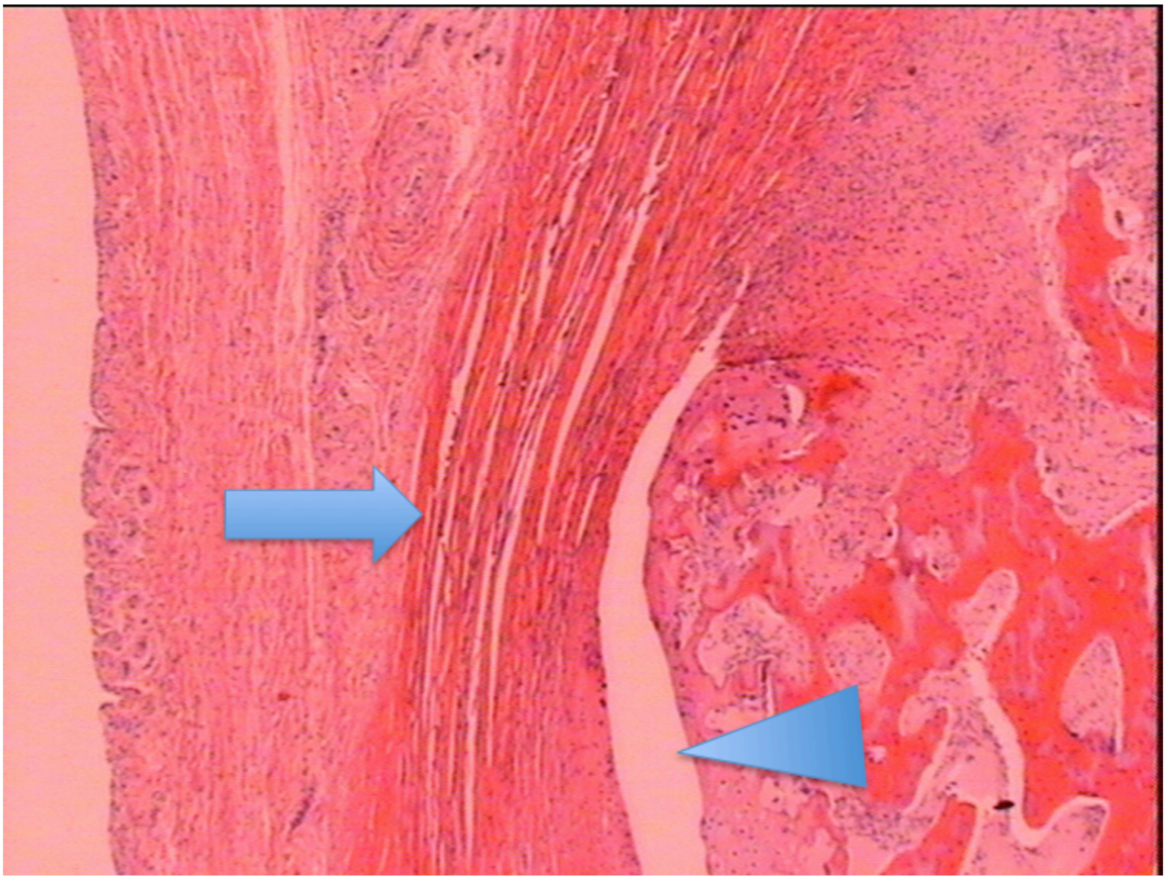

Figure 30 Showing microscopic epiphysiolysis (arrowhead) with the PFC (arrow) intact.

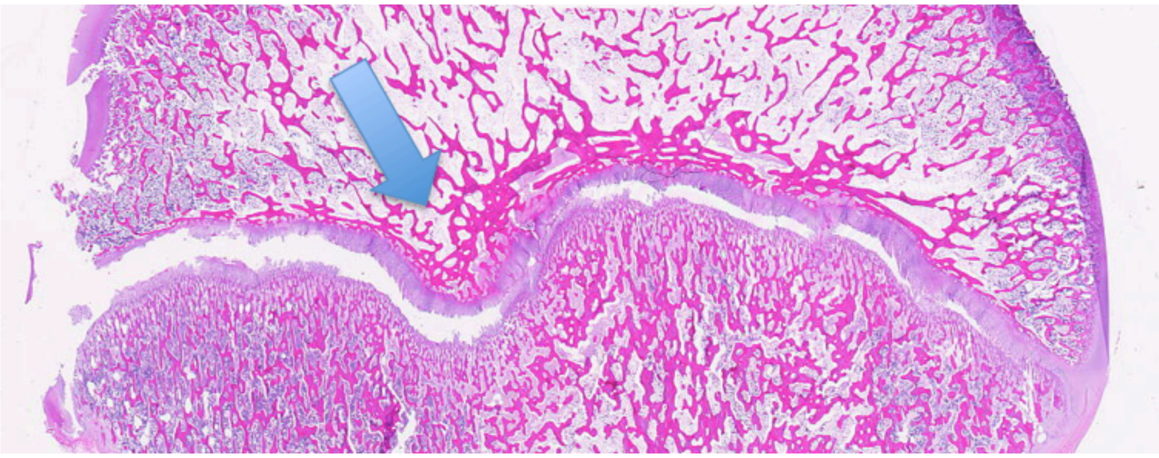

Figure 31 Showing the epiphyseal tubercle (arrow) pressing against the medial wall of the metaphyseal socket.

Conclusion

The experimental biomechanical model showed consistent results when the same loading direction was applied. The proximal femoral epiphyseal plate is the weakest point in the young porcine proximal femur. It is weakest against tensile forces (lateral load) and strongest against compressive forces (vertical load), with strength against shearing forces (anterior load) in between. The epiphyseal tubercle and the PFC stabilise the epiphysis to some degree.

Table 8: Macroscopic characteristics with load and deformation at failure for all specimens.

DIRECTION OF LOAD	SPECIMEN	AP DIAMETER (MM)	ML DIAMETER (MM)	LOAD AT FAILURE (N)	DEFORMATION AT FAILURE (MM)	FOOTPRINT (MM)	FOOTPRINT DISTANCE FROM EPIPHYSEAL LINE (MM)	MACROSCOPIC EPIPHYSEOLYSIS
Anterior load								
	1	35	36	1756	7.4	22 x 8	6	Yes
	2	35	37	1750	7.5	21 x 7	5	Yes
	3	35	36	1679	8.7	20 x 8	5	Yes
	Average	35	36	1728	7.9			
Lateral load								
	1	34	36	1148	7.1	14 x 8	4	Yes
	2	34	36	918	7.0	15 x 4	3	Yes
	3	37	38	920	7.1	17 x 4	4	Yes
	Average	35	37	995	7.1			
Vertical load								
	1	38	39	7397	5.0	25 x 25	5	Yes
	2	37	39	7413	6.6	25 x 25	9	Yes
	3	38	38	7008	6.4	25 x 25	4	Yes
	Average	38	39	7273	6.0			

4. 3. STUDY III

Cyclical loading causes injury in and around the porcine proximal femoral physeal plate: proposed cause of the development of cam deformity in young athletes

Introduction

The repetitive load to which the adolescent athlete's body is exposed during training and competition affects bone growth. Radiological abnormalities in the spine and extremities of adolescent athletes have been well described. The cam deformity of the femoral head-neck junction is an extension of the physeal plate and develops during the adolescent athlete's growth. Studies of the porcine spine have shown that the vertebral endplates, apophyseal rings and intervertebral discs are susceptible to both static and repetitive loads. The proximal physeal plate of the porcine femur is susceptible to static loads, but no studies have been performed on its susceptibility to repetitive loads. The aim of this study was to investigate the susceptibility of the proximal physeal plate of the porcine femur to repetitive loads.

Methods

Using a previously developed model, six proximal femurs from four young (5 months) pigs were loaded repetitively (50,000 cycles), three vertically with 2,500N and three antero-superiorly (simulating 45° flexion) with 2,000N. After loading, all femurs were examined macroscopically, histologically and with MRI. One femur was not loaded and was used as a control.

Results

All specimens were loaded for 50,000 cycles. No macroscopic injuries were detected on any of the specimens after loading. Changes in signal intensity on MRI were seen in all loaded specimens as compared with the unloaded control. These changes, representing fluid redistribution, were mostly noticeable adjacent to the physeal plate, medially to the epiphyseal tubercle (Figure 32). On microscopic examination, injuries in and adjacent to the physeal plate were seen in all the loaded specimens. No injuries were seen in the control specimens (Figure 34). The injuries tended to be located laterally to the epiphyseal tubercle. In the vertically loaded specimens, the damage tended to run perpendicularly to the physeal plate (Figure 33), in contrast to the antero-superiorly loaded specimens, where the damage is more parallel to the plate (Figure 36). In general, more damage was seen in the vertically loaded specimens (Figure 35).

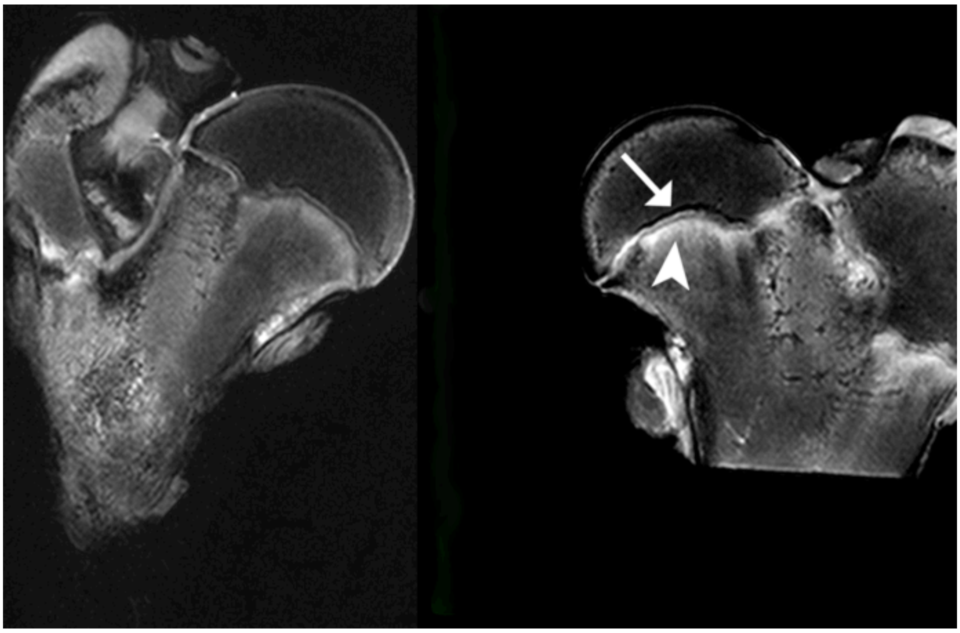

Figure 32 MRI image of the control hip (left) and a vertically loaded hip (right). After loading, a difference in signal intensity was seen medially to the epiphyseal tubercle. A lower signal was seen above the epiphyseal line (white arrow) and a higher signal below the epiphyseal line (white arrowhead).

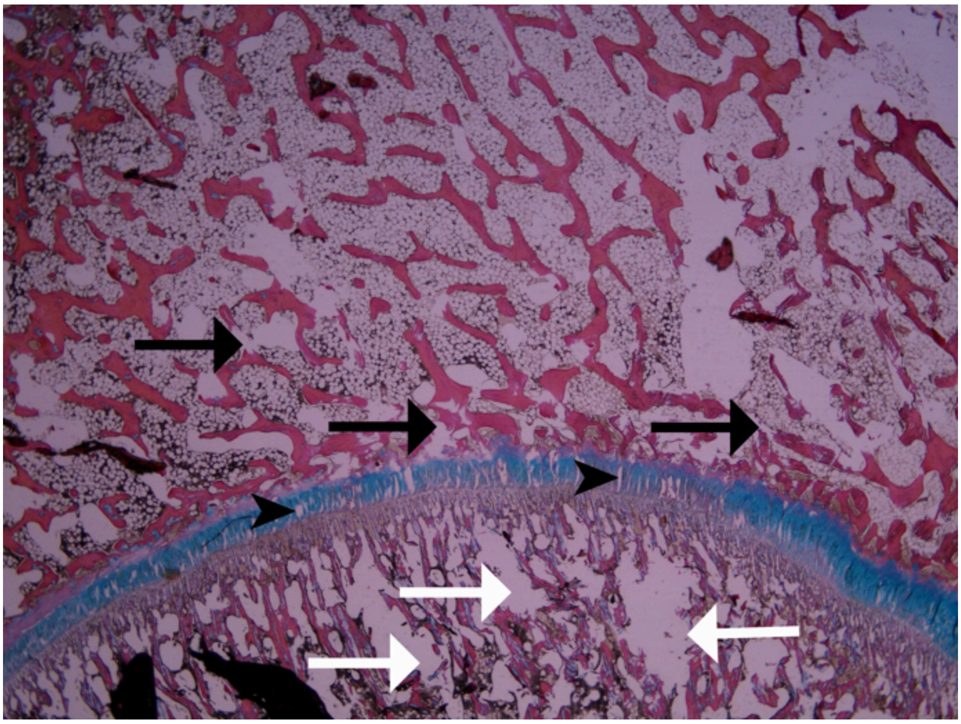

Figure 33 A microscopic photograph of a vertically loaded specimen. Fractures of the epiphyseal bone (above, black arrows) and metaphyseal bone (below, white arrows) are seen and the injuries in the physeal line (black arrowheads) are aligned parallel to the cellular columns of the physeal line.

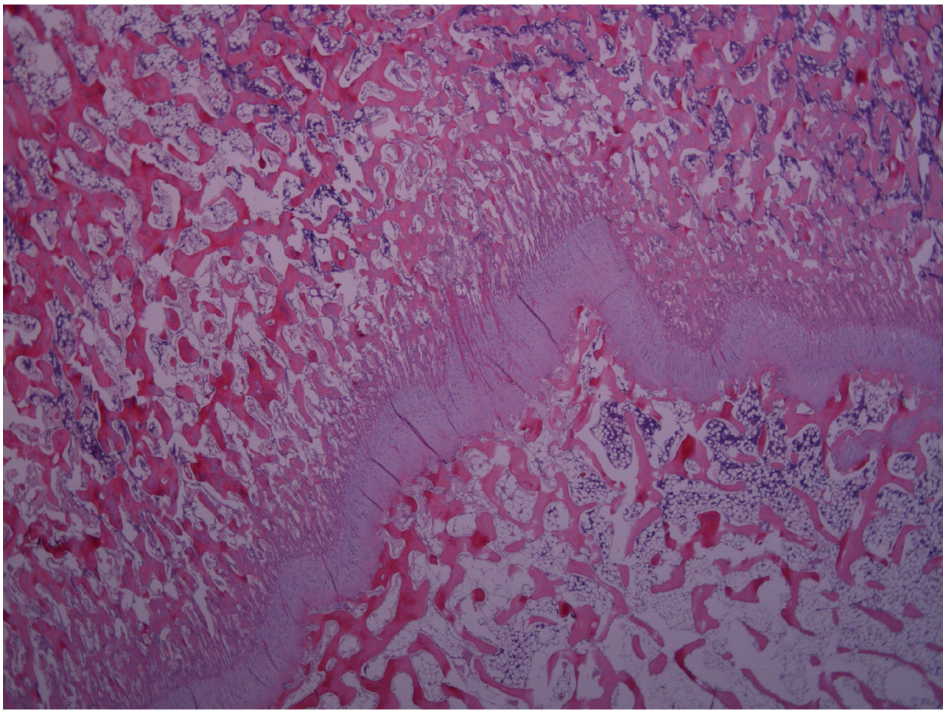

Figure 34 Microscopic photograph showing no microscopic injuries in a non-loaded control specimen.

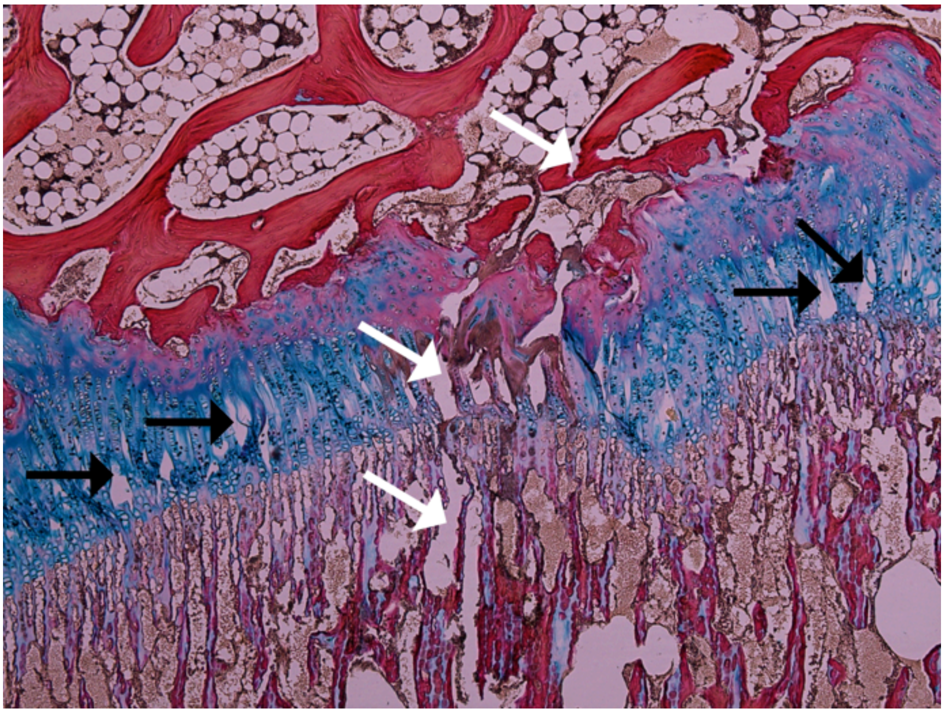

Figure 35 In the vertically loaded specimens, the injuries to the physeal line (black arrows) lay perpendicular to the physeal line, parallel to the cellular columns of the physeal line. On this microscopic picture, a fracture (white arrows) extending from the epiphyseal bone (above) through the physeal line and into metaphyseal bone (below) is seen.

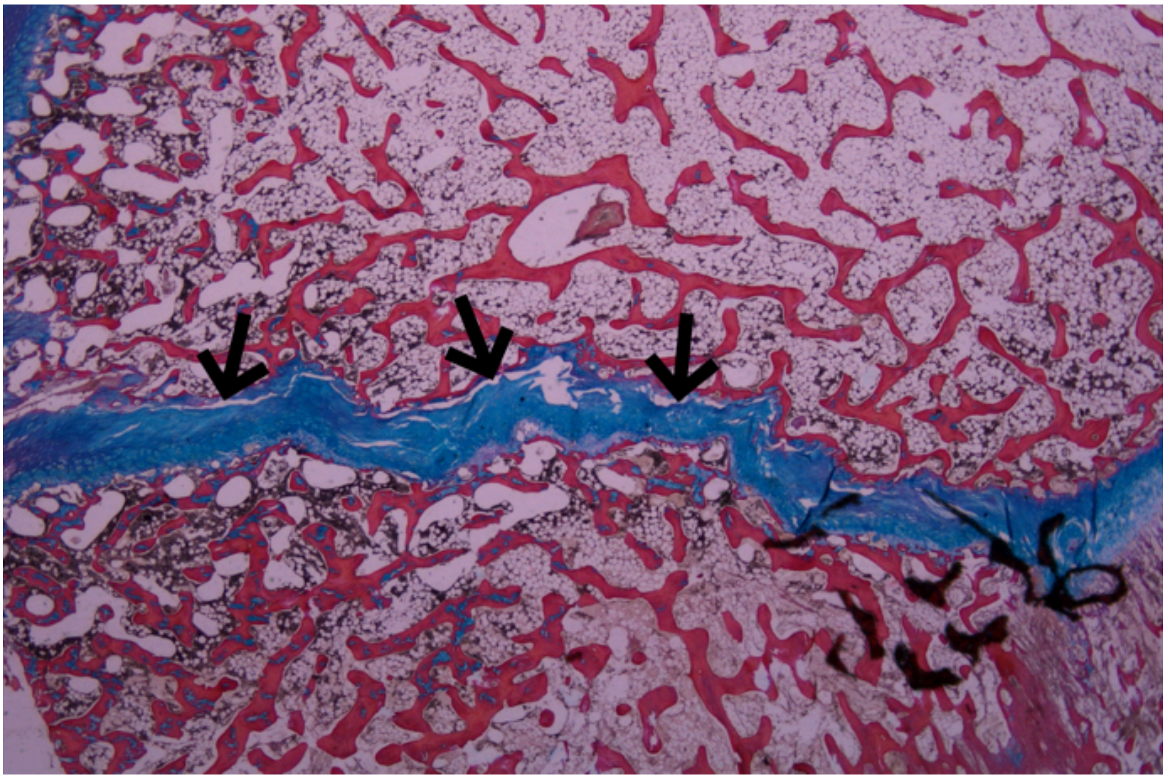

Figure 36 Microscopic photograph of an antero-superiorly loaded specimen. In the antero-superiorly loaded specimens, the injuries lay parallel to the physeal line (black arrows).

Conclusion

Repeated loading of the young porcine hip leads to microscopic injuries in and adjacent to the physeal plate. These injuries can cause growth disturbances in the proximal femur. Similar injuries can be induced in adolescent athletes during vigorous training and offer a plausible explanation of the development of cam deformity.

Table 9: Macroscopic features of the specimens.

SPECIMEN	A-P DIAMETER (MM)	M-L DIAMETER (MM)	MACROSCOPIC DAMAGE PRESENT	HISTOLOGICAL DAMAGE PRESENT
1	35	35	No	Yes
2	38	39	No	Yes
3	37	38	No	Yes
4	38	38	No	Yes
5	38	38	No	Yes
6	36	36	No	Yes
Control	37	38	No	No
Average	37	37.4		

A-P; anterior-posterior, M-L; medial-lateral.

Table 10: MRI findings in the different zones of the femoral head in the specimens. + and – indicate a higher and a lower signal respectively, compared with the control.

SPECIMEN	ZONES							
	1	2	3	4	5	6	7	8
	Adjacent to the physeal plate				Epiphysis		Metaphysis	
	Superior		Inferior					
	Medially	Laterally	Medially	Laterally	Medially	Laterally	Medially	Laterally
1	-	-	+	+	0	0	0	0
2	-	+	+	0	0	0	0	0
3	-	0	+	+	0	0	0	0
4	0	0	+	0	0	0	+	+
5	-	0	+	-	0	0	0	0
6	-	0	0	0	0	-	0	0
Control	0	0	0	0	0	0	0	0

4. 4. STUDY IV

A standardised outcome measure of pain, symptoms and physical function in patients with hip and groin disability due to femoro-acetabular impingement: cross-cultural adaptation and validation of the international Hip Outcome Tool (iHOT12) in Swedish

Introduction
Health-related patient-reported outcomes are becoming the golden standard when evaluating the effects of treatment for different disabilities and diseases. Until recently, there was a lack of standardised outcome measures for active, young and middle-aged patients with hip and groin disability undergoing hip arthroscopy. The iHOT33 and, subsequently, its shorter version, the iHOT12, have addressed this limitation to a certain degree. The aim of this study was to adapt the English version of the iHOT12 for use in Swedish patients and evaluate the adaptation according to the consensus-based standards for the selection of health status measurement instruments (COSMIN) checklist.

Methods
Cross-cultural adaptation was performed in several steps, including translation, back-translation, expert review and pre-testing. The final version was then evaluated for reliability, validity and responsiveness in a clinical study of patients undergoing surgery for femoroacetabular impingement.

Results
Internal consistency measurements revealed a Cronbach's alpha of 0.89. For the test-retest reliability measurements, the ICC ranged from 0.59 to 0.93 for the individual items and was 0.88 for the average score. Wilcoxon's paired test revealed no significant difference between the test and retest scores. Measurement error expressed as SDC ranged from 15.9 to 48.4 at individual level and 3.3 to 10.1 at group level for the individual items. SDC for the average score was 17.1 at individual level and 3.6 at group level.

An exploratory factor analysis revealed two factors with an eigenvalue higher than 1.0, one expressing physical function and the other symptoms. Construct validity was good with all items and the average score of the iHOT12 correlated significantly with all subscales of the HAGOS and the EQ-5D total score.

All items and the average iHOT12 score correlated significantly with a GPE scale. Changes in the GPE scale over time correlated with ES and SRM, with those reporting lower on the GPE scale after four months having lower ES and SRM and vice versa. No floor or ceiling effects were found.

Conclusion
The Swedish version of the iHOT12, the iHOT12-S, is a valid, reliable and responsive instrument that can be used both for research and in a clinical setting.

Table 11 Descriptive statistics and test-retest reliability of the iHOT12-S (n=36).

IHOT 12-S	TEST MEAN (SD)	RE-TEST MEAN (SD)	DIFFERENCE TEST-RE-TEST, MEAN (SD)	SEM	ICC (95% CI)	SDC INDIVIDUAL	SDC GROUP	SPEARMAN r	WILCOXON PAIRED TEST
Q1	33.4 (20.5)	27.7 (18.4)	11.9 (14.0)	12.7	0.58 (0.31-0.76)	35.1	5,8	0.57*	0.12
Q2	61.8 (32.0)	52.3 (29.4)	18.9 (17.6)	17.7	0.67 (0.42-0.82)	49.2	8,0	0.68*	0.03
Q3	53.5 (32.1)	45.1 (34.0)	16.1 (15.7)	15.5	0.78 (0.59-0.88)	43.0	7,0	0.77*	0.04
Q4	61.3 (34.2)	53.1 (34.7)	15.3 (16.3)	15.4	0.80 (0.62-0.89)	42.6	7,1	0.77*	0.05
Q5	54.2 (26.8)	43.0 (27.4)	19.7 (17.9)	18.2	0.56 (0.27-0.75)	50.5	8,4	0.58*	0.01
Q6	44.4 (31.4)	34.3 (29.1)	18.0 (18.5)	17.8	0.66 (0.41-0.82)	49.3	8,0	0.66*	0.01
Q7	28.2 (21.1)	24.5 (18.3)	12.1 (13.6)	12.7	0.58 (0.32-0.76)	35.3	5,9	0.72*	0.20
Q8	74.1 (29.3)	65.9 (31.0)	18.3 (20.8)	19.1	0.60 (0.34-0.77)	53.0	8,8	0.55*	0.09
Q9	63.9 (32.6)	54.1 (34.0)	14.9 (22.5)	18.6	0.69 (0.46-0.83)	51.6	8,6	0.65*	0.04
Q10	18.7 (16.2)	15.0 (19.1)	11.1 (12.8)	11.7	0.56 (0.29-0.74)	32.5	5,4	0.61*	0.13
Q11	22.3 (17.8)	24.0 (22.4)	14.7 (15.5)	14.9	0.45 (0.14-0.68)	41.3	6,9	0.41*	0.93
Q12	17.9 (13.5)	15.5 (13.6)	12.1 (10.5)	11.2	0.31 (-0.16-0.58)	31.0	5,2	0.32	0.57
Avg score	44.5 (15.5)	37.9 (17.2)	9.2 (9.3)	8.9	0.71 (0.41-0.85)	24.8	4,1	0.70*	0.001

*Significant correlation p<0.01
SD, standard deviation; SEM, standard error of mean; ICC, intraclass correlation coefficient; SDC individual, smallest detectable change at individual level; SDC group, smallest detectable change at group level.

Table 12 Spearman's correlation coefficient determined when comparing iHOT12-S questions idividually with the subscales and total score of the EQ5D.

	EQ-5D SUBSCALES					EQ-5D TOTAL SCORE	EQ-5D VAS
	Mobility	Self-care	Usual activities	Pain/discomfort	Anxiety/depression		
Q1	0.30**	0.08	0.24**	0.47**	0.27**	0.45**	0.32**
Q2	0.46**	0.26**	0.29**	0.40**	0.18**	0.46**	0.33**
Q3	0.54**	0.16**	0.28**	0.36**	0.22**	0.46**	0.37**
Q4	0.23**	0.10*	0.21**	0.17**	0.21**	0.28**	0.12**
Q5	0.37**	0.17**	0.34**	0.30**	0.24**	0.41**	0.39**
Q6	0.22**	0.13**	0.24**	0.17**	0.24**	0.27**	0.27**
Q7	0.32**	0.11*	0.27**	0.37**	0.25**	0.40**	0.32**
Q8	0.37**	0.20**	0.32**	0.32**	0.22**	0.43**	0.35**
Q9	0.28**	0.16**	0.28**	0.31**	0.26**	0.39**	0.34**
Q10	0.23**	0.09*	0.20**	0.34**	0.30**	0.38**	0.32**
Q11	0.19**	0.13**	0.18**	0.19**	0.29**	0.30**	0.29**
Q12	0.20**	0.06	0.23**	0.33**	0.31**	0.36**	0.35**
Average	0.49**	0.20**	0.38**	0.46**	0.34**	0.56**	0.44**

*=p<0.05, **=p<0.01

Table 13 Spearman's correlation coefficient determined when comparing iHOT12-S questions individually with the subscales of the HAGOS.

	PAIN	SYMPTOMS	ADL	SPORT/RECREATION	PA	QOL
Q1	0.53**	0.44**	0.50**	0.45**	0.25**	0.47**
Q2	0.61**	0.52**	0.70**	0.54**	0.17**	0.36**
Q3	0.59**	0.45**	0.59**	0.56**	0.38**	0.48**
Q4	0.25**	0.45**	0.24**	0.29**	0.10*	0.26**
Q5	0.49**	0.42**	0.57**	0.56**	0.33**	0.46**
Q6	0.29**	0.34**	0.34**	0.50**	0.30**	0.35**
Q7	0.50**	0.41**	0.47**	0.53**	0.39**	0.45**
Q8	0.50**	0.35**	0.55**	0.47**	0.25**	0.44**
Q9	0.45**	0.40**	0.48**	0.43**	0.27**	0.39**
Q10	0.38**	0.33**	0.35**	0.34**	0.27**	0.54**
Q11	0.30**	0.27**	0.28**	0.37**	0.29**	0.47**
Q12	0.29**	0.28**	0.27**	0.36**	0.33**	0.55**
Average	0.65**	0.58**	0.68**	0.67**	0.37**	0.61**

*=p<0.05, **=p<0.01

Table 14 Responsiveness of the iHOT12-S measured against different change scores in the GPE scale.

	GPE SCORE (N=495)	GPE SCORE AT LEAST 20 POINTS LOWER AT FOUR MONTHS (N=19)		GPE SCORE SAME OR WITHIN 20 POINTS AT FOUR MONTHS (N=102)		GPE SCORE AT LEAST 20 POINTS HIGHER AT FOUR MONTHS (N=135)	
iHOT12-S	Spearman *r*	SRM	ES	SRM	ES	SRM	ES
Q1	0.43*	-0.48	-0.42	0.62	0.68	1.20	1.73
Q2	0.46*	-0.39	-0.34	0.30	0.30	0.99	0.95
Q3	0.36*	-0.56	-0.57	0.32	0.29	0.79	0.84
Q4	0.21*	-0.36	-0.44	0.00	0.00	0.52	0.55
Q5	0.38*	-0.47	-0.49	0.30	0.29	0.71	0.73
Q6	0.34*	-0.79	-0.55	0.19	0.21	0.75	0.97
Q7	0.43*	-0.43	-0.34	0.81	0.81	1.16	1.56
Q8	0.33*	-0.35	-0.40	0.28	0.27	0.65	0.64
Q9	0.30*	-0.54	-0.58	0.38	0.32	0.72	0.75
Q10	0.38*	-0.43	-0.53	0.46	0.60	1.02	1.70
Q11	0.31*	-0.30	-0.41	0.40	0.54	0.91	1.50
Q12	0.40*	-0.37	-0.41	0.54	0.73	1.11	2.34
Total average	0.52*	-0.81	-0.64	0.58	0.57	1.31	1.72

*Significant correlations p<0.01
GPE, global perceived effect; SRM, standardised response mean; ES, effect size.

Table 15 iHOT12-S score at baseline and at four months with frequencies of lowest (floor effect) and highest (ceiling effect) scores.

		MEAN	SD	MEDIAN	RANGE	FLOOR EFFECT (%)	CEILING EFFECT (%)	MIC
iHOT12-S at baseline (n=502)								
	Q1	36.2	22.2	30.0	0-100	7 (1.4)	1 (0.2)	11.1
	Q2	55.2	28.4	50.0	0-100	2 (0.4)	22 (4.4)	14.2
	Q3	44.7	30.7	37.0	0-100	10 (2.0)	14 (2.8)	15.4
	Q4	56.8	31.3	50.0	0-100	8 (1.6)	30 (6.0)	15.7
	Q5	47.9	28.4	44.0	0-100	4 (0.8)	15 (3.0)	14.2
	Q6	35.4	27.9	28.0	0-100	14 (2.8)	11 (2.2)	14.0
	Q7	28.8	24.5	22.0	0-100	19 (3.8)	3 (0.6)	12.3
	Q8	64.0	30.3	69.0	0-100	6 (1.2)	50 (10.0)	15.2
	Q9	55.0	31.9	50.0	0-100	11 (2.2)	33 (6.6)	16.0
	Q10	21.1	21.5	14.0	0-96	38 (7.6)	0 (0)	10.8
	Q11	23.1	21.4	18.0	0-100	44 (8.8)	3 (0.6)	10.7
	Q12	18.9	18.2	15.0	0-91	39 (7.8)	0 (0)	9.1
	Total average	39.3	17.7	37.6	1-96	0 (0)	0 (0)	8.9
iHOT12-S at four months (n=260)								
	Q1	36.7	21.5	31.0	0-99	2 (0.8)	0 (0)	10.8
	Q2	56.9	28.1	50.0	2-100	0 (0)	12 (4.6)	14.1
	Q3	45.4	30.2	38.5	0-100	5 (1.9)	7 (2.7)	15.1
	Q4	58.4	30.6	50.0	0-100	3 (1.2)	15 (5.8)	15.3
	Q5	49.9	28.7	50.0	0-100	1 (0.4)	9 (3.5)	14.4
	Q6	34.9	27.4	27.5	0-100	7 (2.7)	2 (0.8)	13.7
	Q7	29.0	24.5	23.0	0-100	10 (3.8)	1 (0.4)	12.3
	Q8	64.3	28.6	68.0	0-100	2 (0.8)	18 (6.9)	14.3
	Q9	55.8	31.0	50.0	0-100	7 (2.7)	11 (4.2)	15.5
	Q10	20.7	21.6	14.0	0-90	17 (6.5)	0 (0)	10.8
	Q11	22.9	21.6	17.0	0-100	18 (6.9)	2 (0.8)	10.8
	Q12	19.0	18.3	15.0	0-89	17 (6.5)	0 (0)	9.2
	Total averager	39.9	17.4	38.7	4-89	0 (0)	0 (0)	8.7

MIC, minimal important change.

4. 5. STUDY V

Cross-cultural adaptation to Swedish and validation of the Copenhagen Hip and Groin Outcome Score (HAGOS) for pain, symptoms and physical function in patients with hip and groin disability due to femoroacetabular impingement

Introduction

Until recently, there was a lack of standardised outcome measures for active, young and middle-aged patients with hip and groin disability. The Copenhagen Hip and Groin Outcome Score (HAGOS) has addressed this lack to a certain degree. The aim of this study was to adapt the Danish version of the Copenhagen HAGOS for use in Swedish patients and evaluate its psychometric properties according to the consensus-based standards for the selection of health status measurement instruments (COSMIN) checklist.

Methods

Cross-cultural adaptation was performed in several steps, including translation, back-translation, expert review and pre-testing. The psychometric properties of the adapted versions were evaluated in a clinical study with 502 patients undergoing surgery for femoroacetabular impingement.

Results

A total of 502 patients completed the questionnaire at baseline. Within three weeks, 26 patients completed the questionnaire for a second time for test-retest reliability evaluation. At four months post-surgery, 360 patients completed the questionnaire for responsiveness measurements.

Internal consistency, measured as Cronbach's alpha, ranged from 0.77 to 0.89 for the six different subscales. Test-retest reliability measurements revealed an ICC ranging from 0.81 to 0.87. No statistical difference on a Wilcoxon's paired test was seen between the test and retest scores. Measurement error represented by the smallest detectable change (SDC) ranged from 7.8 to 16.1 at individual level and from 1.5 to 3.2 at group level.

An exploratory factor analysis of each subscale revealed that all subscales loaded with one strong factor with an eigenvalue over 1.0. All subscales of the HAGOS showed significant correlations with all items and the average score of the iHOT12-S, the EQ-5D total score and the EQ-5D VAS score, revealing good construct validity.

Good responsiveness was found for all subscales of the HAGOS correlating with a GPE scale and the ES and SRM were higher for those reporting higher GPE scores at the four-month follow-up and vice versa.

Floor effect was seen in the physical activity subscale both at baseline and at the four-month follow-up, with 31.5% and

21.9% respectively reporting the lowest possible score. At the four-month follow-up, a ceiling effect was detected for the function in the daily living subscale, with 16.9% reporting the highest score.

Conclusion

The Swedish version of the HAGOS, the HAGOS-S, is a valid, reliable and responsive instrument that can be used for research and in a clinical setting at individual and group level.

Table 16 Descriptive statistics and test-retest reliability of the six HAGOS-S subscales (n=26).

SUB-SCALES	TEST MEAN (SD)	RE-TEST MEAN (SD)	P-VALUE	DIFFERENCE TEST-RE-TEST, MEAN (SD)	SEM	ICC (95% CI)	SDC IND	SDC GRP
Sympt	56.5 (15.4)	52.7 (17.5)	0.10, ns	7.3 (7.9)	3.0	0.81 (0.64-0.96)	8.3	1.6
Pain	53.4 (14.9)	51.9 (15.9)	0.27, ns	7.6 (4.9)	2.9	0.83 (0.66-0.92)	8.0	1.6
Func DL	61.7 (24.8)	58.7 (22.1)	0.30, ns	8.5 (9.1)	4.9	0.87 (0.72-0.94)	13.6	2.7
Func Sp	41.6 (22.9)	38.0 (23.6)	0.15, ns	11.5 (9.2)	4.5	0.81 (0.62-0.91)	12.5	2.4
Phys	32.2 (29.4)	28.8 (29.5)	0.40, ns	11.1 (14.7)	5.8	0.81 (0.62-0.91)	16.1	3.2
QoL	30.0 (14.1)	29.4 (12.5)	0.77, ns	5.6 (4.5)	2.8	0.85 (0.70-0.93)	7.8	1.5

Sympt; Symptoms in hip and/or groin, Pain; Pain in hip and/or groin, Func DL; Function in daily living, Func Sp; Function in sport and recreation, Phys; Participation in physical activities, QoL; Hip- and/or groin-related quality of life, SD; Standard deviation, p-value; for Wilcoxon's paired test, between test and retest, ns; non-significant, SEM; Standard error of the mean, ICC; Intraclass correlation coefficient, 95% ci; 95% confidence interval, SDC ind; Smallest detectable change at individual level, SDC grp; Smallest detectable change at group level.

Table 17 Chronbach's alpha (Cα) for internal consistency (n=502) and factor analysis (n=502) with eigenvalue (EV) and degree of variance explained in per cent (%) for the six HAGOS-S subscales.

	Cα	EV	%
Sympt	0.77	3.1	45%
Pain	0.88	5.1	51%
Func DL	0.89	3.5	70%
Func Sp	0.89	4.6	57%
Phys	0.84	1.7	86%
QoL	0.83	3.0	60%

Sympt; Symptoms in hip and/or groin, Pain; Pain in hip and/or groin, Func DL; Function in daily living, Func Sp; Function in sport and recreation, Phys; Participation in physical activities, QoL; Hip- and/or groin-related quality of life .

Table 18 Spearman's correlation coefficients at baseline for HAGOS-S subscales and EQ-5D-S subscales, total score and VAS (n=495).

	HAGOS-S					
	Sympt	Pain	Func DL	Func Sp	Phys	QoL
Mobility	-0.54**	-0.48**	-0.57**	-0.51**	-0.25**	-0.44**
Self-care	-0.20**	-0.21**	-0.27**	-0.23**	-0.10**	-0.14**
Usual activities	-0.31**	-0.24**	-0.33**	-0.37**	-0.43**	-0.42**
Pain/discomfort	-0.50**	-0.39**	-0.47**	-0.38**	-0.22**	-0.45**
Anxiety/depression	-0.24**	-0.21**	-0.24**	-0.27**	-0.29**	-0.50**
Total score	0.57**	0.47**	0.57**	0.52**	0.40**	0.60**
VAS	0.46**	0.33**	0.44**	0.45**	0.40**	0.55**

Sympt; Symptoms in hip and/or groin, Pain; Pain in hip and/or groin, Func DL; Function in daily living, Func Sp; Function in sport and recreation, Phys; Participation in physical activities, QoL; Hip- and/or groin-related quality of life, **; Significant correlation p<0.01.

Table 19 Spearman's correlation coefficients at baseline for the 12 items and average score for the iHOT12-S and the six subscales of the HAGOS-S (n=495).

	HAGOS-S					
	Sympt	Pain	Func DL	Func Sp	Phys	QOL
Q1	0.44**	0.53**	0.50**	0.45**	0.25**	0.47**
Q2	0.52**	0.61**	0.70**	0.54**	0.17**	0.36**
Q3	0.45**	0.59**	0.59**	0.56**	0.38**	0.48**
Q4	0.45**	0.25**	0.24**	0.29**	0.10*	0.26**
Q5	0.42**	0.49**	0.57**	0.56**	0.33**	0.46**
Q6	0.34**	0.29**	0.34**	0.50**	0.30**	0.35**
Q7	0.41**	0.50**	0.47**	0.53**	0.39**	0.45**
Q8	0.35**	0.50**	0.55**	0.47**	0.25**	0.44**
Q9	0.40**	0.45**	0.48**	0.43**	0.27**	0.39**
Q10	0.33**	0.38**	0.35**	0.34**	0.27**	0.54**
Q11	0.27**	0.30**	0.28**	0.37**	0.29**	0.47**
Q12	0.28**	0.29**	0.27**	0.36**	0.33**	0.55**
Total	0.58**	0.65**	0.68**	0.67**	0.37**	0.61**

Sympt; Symptoms in hip and/or groin, Pain; Pain in hip and/or groin, Func DL; Function in daily living, Func Sp; Function in sport and recreation, Phys; Participation in physical activities, QoL; Hip- and/or groin-related quality of life, *; Significant correlations $p<0.05$, **; Significant correlations $p<0.01$.

Table 20 Responsiveness of the HAGOS-S measured against different change in scores on the GPE scale.

	GPE (N=495)	GPE 20 P LOWER AT FOUR MONTHS (N=26)		GPE WITHIN +/- 20 P AT FOUR MONTHS (N=147)		GPE 20 P HIGHER AT FOUR MONTHS (N=187)	
HAGOS-S	r_s	SRM	ES	SRM	ES	SRM	ES
Sympt	0.52**	-0.24	-0.19	0.51	0.48	1.42	1.37
Pain	0.62**	-0.27	-0.22	0.63	0.54	1.61	1.42
Func DL	0.58**	-0.39	-0.23	0.47	0.37	1.31	1.17
Func Sp	0.58**	-0.59	-0.36	0.33	0.35	1.45	1.55
Phys Act	0.40**	-0.62	-0.40	0.20	0.23	0.74	1.07
QoL	0.59**	-0.56	-0.44	0.46	0.48	1.38	1.87

Sympt; Symptoms in hip and/or groin, Pain; Pain in hip and/or groin, Func DL; Function in daily living, Func Sp; Function in sport and recreation, Phys; Participation in physical activities, QoL; Hip- and/or groin-related quality of life, **; Significant correlations p<0.01, GPE; Global perceived effect, SRM; Standardised response mean, ES; Effect size.

Table 21 The HAGOS-S score at baseline and at four months with frequencies of lowest (floor effect) and highest (ceiling effect) scores.

BASELINE (N=502)	MEAN	SD	MEDIAN	MIN-MAX	FLOOR EFFECT (%)	CEILING EFFECT (%)	MIC
Sympt	50.1	18.5	50.0	0-100	1 (0.2)	3 (0.6)	9.3
Pain	54.9	19.3	52.5	0-100	1 (0.2)	1 (0.2)	9.7
ADL	57.5	23.5	55.0	0-100	3 (0.6)	20 (4.0)	11.8
Sport	37.4	21.6	34.4	0-100	13 (2.6)	1 (0.2)	10.8
Phys Act	25.7	26.1	25.0	0-100	158 (31.5)	12 (2.4)	13.1
Qol	30.0	17.6	30.0	0-100	13 (2.6)	1 (0.2)	8.8
FOUR MONTHS (N=360)	**MEAN**	**SD**	**MEDIAN**	**MIN-MAX**	**FLOOR EFFECT (%)**	**CEILING EFFECT (%)**	**MIC**
Sympt	67.2	18.9	67.9	14-100	0 (0.0)	7 (1.9)	9.5
Pain	73.0	19.5	75.0	10-100	0 (0.0)	25 (6.9)	9.8
ADL	75.3	22.0	80.0	15-100	0 (0.0)	61 (16.9)	11.0
Sport	56.6	26.1	56.3	0-100	2 (0.6)	14 (3.9)	13.1
Phys Act	41.9	33.8	37.5	0-100	79 (21.9)	37 (10.3)	16.9
Qol	49.3	25.3	50.0	0-100	5 (1.4)	16 (4.4)	12.7

Sympt; Symptoms in hip and/or groin, Pain; Pain in hip and/or groin, ADL; Function in daily living, Sport; Function in sport and recreation, Phys Act; Participation in physical activities, QoL; Hip- and/or groin-related quality of life, SD; Standard deviation, MIC; Minimal important change.

Páll Sigurgeir Jónasson

5

DISCUSSION

DISCUSSION

5. 1. CLINICAL STUDY

The main finding in the clinical study was that, although there were no differences in the radiographic criteria used to quantify either the cam or the pincer deformity, the athletes had a significantly lower range of motion compared with the controls. This reduced ROM can therefore not be explained by the presence of FAI alone.

Range of motion

The ROM differed mainly in external and internal rotation. The internal and external rotation of the athletes is similar to that previously reported by Kapron et al. (Kapron et al. 2012). The external rotation in the control group is somewhat higher than that reported in an asymptomatic population, while the internal rotation is lower (Magee 2014). The external rotation appears to be more affected in individuals where the cam deformity is located superiorly on the head-neck junction, while the internal rotation is more affected if the deformity is located more anteriorly. This is important as, if the patient has decreased internal rotation, a cam deformity can be present. This is best visualised on a modified Lauenstein view and can easily be missed if only AP views are obtained.

Alpha angle

The alpha angle in an asymptomatic male population has been reported to be between 45-55° (Gosvig 2007, Pollard 2010). The alpha angle in the present control population was higher (62°) on the modified Lauenstein projection than previously reported. The reason for this is not known. The athletes tended to have higher alpha angles, although this was not significant. Larger groups might have displayed a significant difference in alpha angles, but the clinical relevance would be debatable.

The athletes had significantly larger femoral heads. We doubt whether this has any relevance to the results in the present study and hypothesise that it is simply a product of the advantage larger players have in both ice-hockey and football. Larger players are therefore more likely to continue playing at elite level than smaller players. The average height of the subjects in both groups is unknown.

Osteoarthritis

The presence of osteoarthritis of the hip as measured with the Tönnis classification was more common in the athletes. Hip osteoarthritis is known to cause reduced ROM (Birrell et al. 2001), but individuals with osteoarthritis, as classified by the Tönnis classification, did not have lower ROM, except in flexion of the right hip. The difference in pain on the FADDIR and FABER tests can also be caused by the osteoarthritic changes that were more common in the athletes. Pain on FABER correlated with arthritic changes in the right hip, but this did not apply to pain on the FADDIR test. For the left hip, it was the other way around, as correlations were found between arthritic changes and pain on the FADDIR test but not for pain on the FABER test. Pain on the FADDIR and FABER tests can be caused by other injuries not detected on plain radiographs, such as cartilage or labrum damage.

It can also be speculated that, in the presence of FAI, high-load athletic activities lead to early degenerative osteoarthritis and might explain why osteoarthritis of the hip is more common in the athletic population (Gouttebarge et al. 2015). In the present study, it was shown that there were correlations between osteoarthritis and cam morphology in the superior head-neck junction (pistol grip deformity on the AP pelvic view). Similar correlations were not found between the more anteriorly placed cam morphology (cam deformity on the modified Lauenstein view) and osteoarthritis. This might indicate that, when the cam deformity is located more superiorly on the head-neck junction, the risk of developing osteoarthritis is higher than if it is placed more anteriorly, especially in the elite athlete. Further studies are needed before any firm conclusions about this finding can be drawn.

We did not test for intra- or inter-observer reliability. Previous studies have shown that standardised ROM measurements using a goniometer have good reliability (Nussbaumer et al. 2010; Prather et al. 2010). The reliability of clinical tests for FAI varies in different studies. The FABER test usually shows good reliability and the FADDIR test is the one most often reported in studies of FAI and we deem its reliability adequate (Martin and Sekiya 2008; Prather et al. 2010; Ratzlaff et al. 2013; Cibere et al. 2008). Both tests have been shown to be sensitive, but, with regard to FAI, they often lack specificity (Clohisy et al. 2009b; Maslowski et al. 2010).

Numerous studies of the reliability of radiographic evaluation of the hip have been reported. The reliability of the different measurements varies (Clohisy et al. 2009a), but the alpha angle, head-neck offset, centre-edge angle, cross-over sign and Tönnis grade generally show good reliability (Clohisy et al. 2007; Gosvig et al. 2007; Nelitz et al. 1999; Clohisy et al. 2009a).

5. 2. BIOMECHANICAL STUDIES

In the biomechanical studies, an animal model that was consistent and easy to set up was developed. The age of the subjects and size of the specimens were comparable in both studies.

Examination after loading
The procedure for the preparation of the sections planned for microscopy has previously been shown not to induce any structural changes (Baranto et al. 2005a; Baranto et al. 2005b) and this was further confirmed for the control specimen.

Static load to failure

Static loading to failure resulted in either an epiphyseolysis or a fracture-epiphyserolysis in all specimens and macroscopic injuries were detected in all specimens. The vertical load mainly caused failure in the ossifying zone of the epiphyseal plate, while a more random pattern of failure between different epiphyseal zones was noted when other loading directions were applied. In a study of cattle, Moen et al. reported that compressive forces tended to cause failure in the ossifying zone (Moen and Pelker 1984).

Chung et al. (Chung et al. 1976) reported a significant decrease in shear strength when the PFC was excised. They loaded their specimens anteriorly. In the present study, all but one slice from the anteriorly loaded specimens showed an undamaged PFC, while some PFC damage was seen in all laterally loaded specimens (Figure 37-38). This indicates that the PFC performs a stabilising function, at least when the epiphysis is loaded anteriorly. In the vertically loaded specimens, the integrity of the PFC could not be assessed in six of 12 slices. The disappearance of the metaphyseal part during the preparation of the slices might indicate that the PFC was damaged.

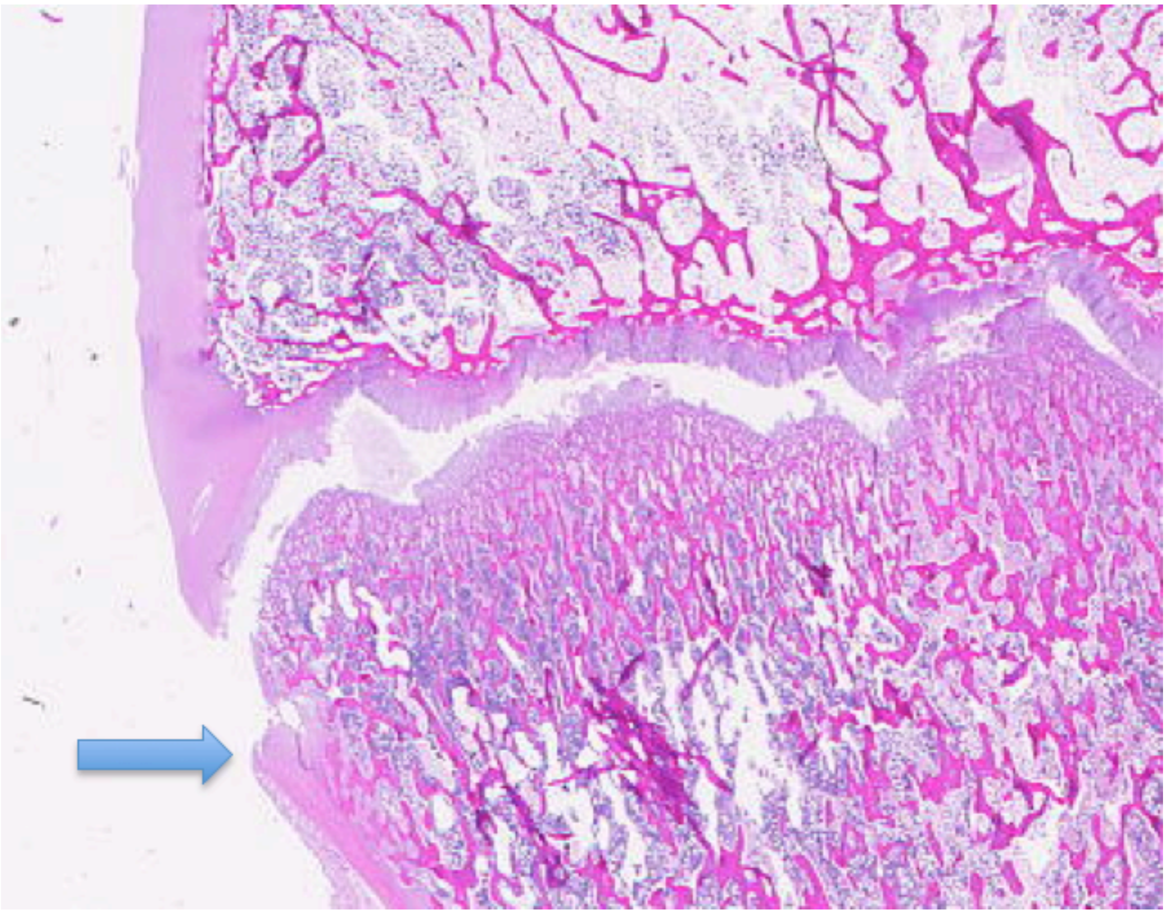

Figure 37 Showing epiphysiolysis with a damaged PFC (arrow).

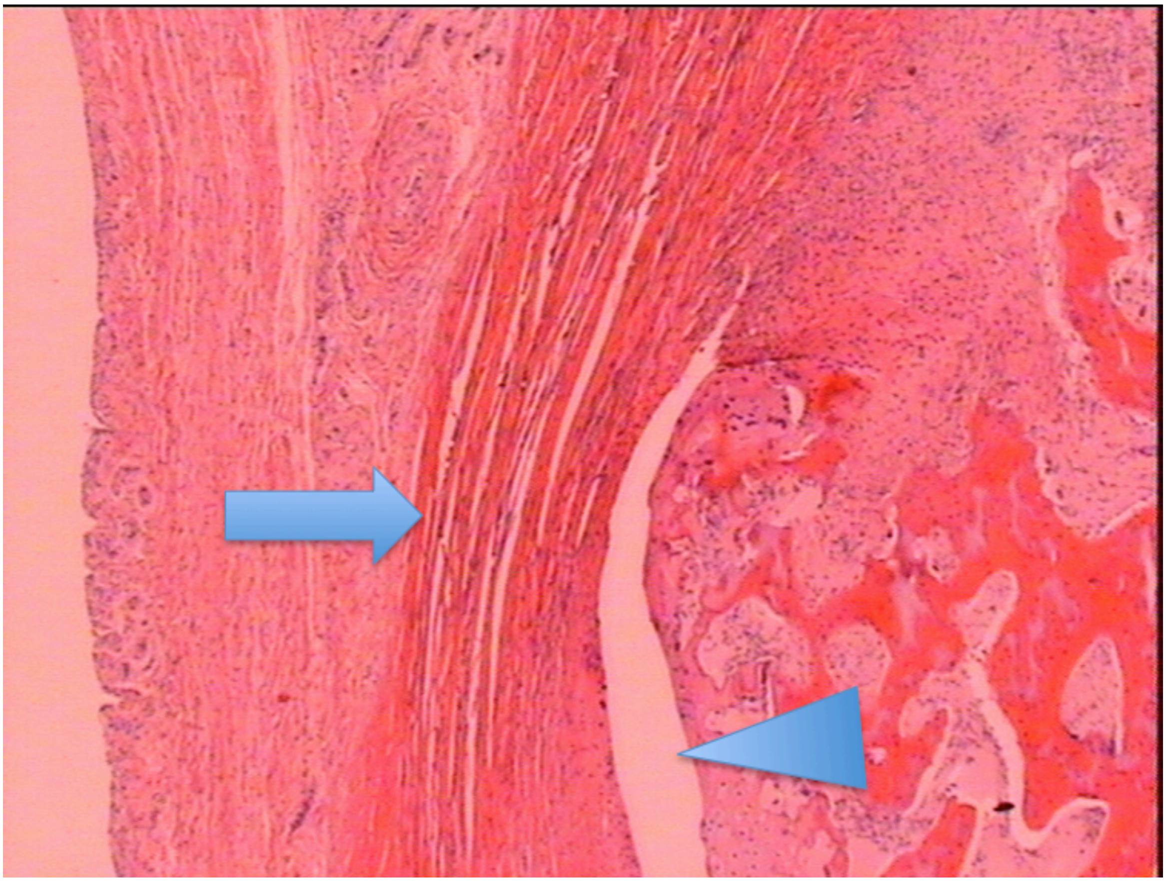

Figure 38 Showing microscopic epiphysiolysis (arrowhead) with the PFC (arrow) intact.

The epiphyseal tubercle was identified in all specimens apart from one of the anteriorly loaded specimens (Figure 39). On the slices from the laterally loaded specimens, where the tubercle was identified, the tubercle was shown to be pressing against the metaphyseal socket, stopping the sliding of the epiphysis (Figure 40). The same finding was seen on the slices from the vertically loaded specimens, where the tubercle appears to stop the epiphysis in its slide. Due to the compressive forces applied in the vertically loaded specimens, the tubercle compresses the medial wall of the socket, resulting in a fracture of the metaphysis through the medial cortex instead of dislodging the tubercle from the socket. This implies that the tubercle has an important stabilising function during vertical and lateral loading.

Figure 39 Porcine proximal femur split coronally. The major trochanter is relatively larger than in a human and the femoral neck shorter and broader. The growth plate and the epiphyseal tubercle are clearly visible in this specimen (arrow).

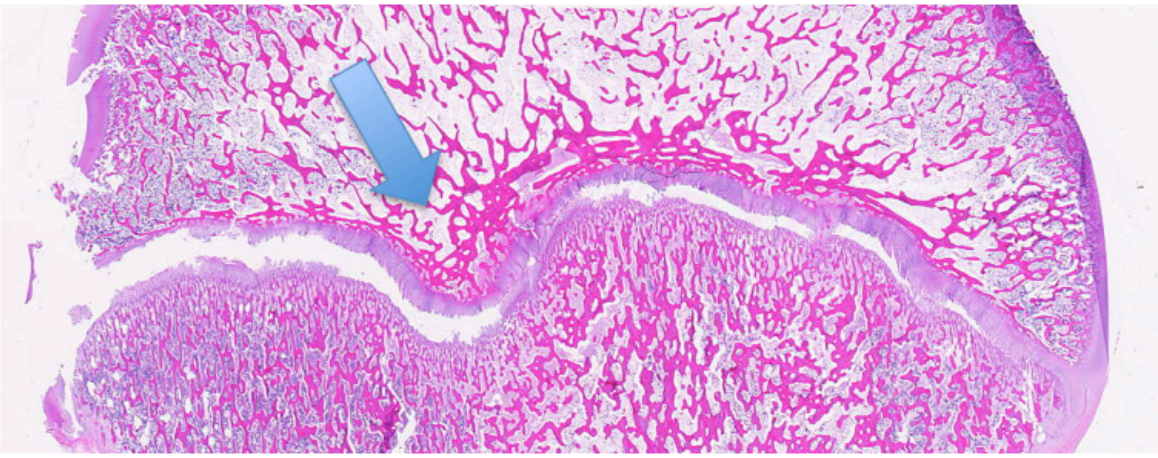

Figure 40 Showing the epiphyseal tubercle (arrow) pressing against the medial wall of the metaphyseal socket.

Repeated sub-failure load

When loaded repeatedly with 50,000 cycles, the specimens showed no macroscopic signs of injury, but microscopic injuries were seen in all specimens in and/or adjacent to the physeal plate. In the vertically loaded specimens, injuries were seen both in and adjacent to the physeal plate, while physeal plate injuries predominated in the antero-superiorly loaded specimens. The physeal plate damage tended to be located perpendicularly to the plate in the vertically loaded specimens but parallel to the plate in the antero-superiorly loaded specimens. It is possible to speculate that more shearing forces are applied to the physeal plate in the antero-superiorly loaded specimens and this explains the difference in injury patterns between different loading directions.

MRI showed fluid redistribution in and around the physeal plate of all specimens. Differences on MRI were predominantly medial to the epiphyseal tubercle, while microscopic injuries were predominantly found laterally to the epiphyseal tubercle. This could be explained by the stabilising function of the epiphyseal tubercle (Jónasson et al. 2014; Tayton 2009). The ET causes the majority of the load to be distributed laterally to the tubercle, thereby causing fractures, while the minority of the load is evenly distributed medially, causing only fluid redistribution. This might also explain why the growth disturbtion only occurs antero-superiorly, with other parts of the physis guarded by the ET.

Load

Static load at failure was lowest for the laterally loaded specimens (995 N) and highest for the vertically loaded specimens (7,273 N). The highest strength was to be expected in the vertically loaded specimens, where the loading direction is comparable to the loading direction in vivo (Bergmann et al. 2001; Bergmann et al. 2004; Brand 1982; Correa et al. 2010).

When repetitive loading was applied, we decided to use about 35-40% of the failure load. As no static failure load data were available, the failure load of the antero-superiorly loaded specimens was estimated to be between the vertical failure load (7,273 N) and the anterior failure load (1,728 N). This resulted in 2,500 N for the vertically loaded specimens (35% failure load) and 2,000 N for the antero-superiorly loaded specimens (40% estimated failure load).

Hip joint loading has been shown to reach levels of up to nine times body weight during different daily activities (Bergmann et al. 2001; Bergmann et al. 1993, 2004; Cleather et al. 2013). The specimens used in this study came from animals weighing approximately 90 kg. The size and shear strength of the specimens are comparable to those of a 10- to 12-year-old child (Chung et al. 1976; Ipsen et al. 2002). The load levels that were chosen are more than twice the body weight (2.2-2.7). Weight distribution in a pig is approximately 60% front and 40% rear limbs (Meijer et al. 2014). The stance load is thereby approximately 20% on one hind limb or aproximately 18 kg in the animals used in the present study. However, it is important to recognise that the stance load is not equivalent to the hip joint load. To our knowledge, no data that quantify the load and movement in the porcine hip joint during daily activity have been presented. If we relate our data to the human hip, with the average 12-year-old boy weighing around 40 kg, the loads applied in our study are about six times their body weight (5.1-6.4). Although comparisons between the porcine model used in the present study and the conditions in the human hip are open to debate, we conclude that the load applied in this study is well within the physiological range possible during sporting activities. Based on estimations of the load to which a human hip joint is subjected during activity, it is believed that the load levels chosen in the present study are reasonable and perhaps even underestimated.

Cycles

In a previous study, in which cyclical loading was applied with 20,000 cycles to the porcine spine, no differences were seen in failure load compared with non-cyclically loaded spines (Thoreson et al. 2010). The number of cycles in the present study (50,000) can be regarded as high, equal to running four marathons (Thoreson et al. 2010), but the amount of training performed by many elite athletes is fairly large. The number of cycles was used to correspond to a weekly cumulative load exposure during sport activities, e.g. a long-distance runner or football player training between 11 and 16 hours a week. Further research is needed to investigate the effect of load level and the number of load cycles on the fatigue properties of the femoral head. The loading frequency (2Hz) represents a good compromise between strain rate and exposure time in order to minimise the impact of dehydration. It is also closer to a normal running (1.5 Hz) cadence as opposed to a faster load set-up.

Loading directions

The load set-up in the present model resulted primarily in a tensile load over the epiphyseal plate in the laterally loaded specimens, a shear load in the anteriorly loaded specimens and a compressive load in those loaded vertically. When loaded antero-superiorly, the physeal plate is subjected to a combination of compressive and shearing forces.

Anterior and lateral loading forces around the femoral head are small during routine activities. Biomechanical studies have shown that, during routine activities, vertical load dominates (Bergmann et al. 2001; Bergmann et al. 2004; Brand 1982; Correa et al. 2010). The way loading occurs during sports and in deep flexion is, however, unknown. Muscle action and ligament constraints around the hip joint probably prevent the joint from being loaded from an anterior direction in vivo to a certain degree, but anterior load appears to increase in deep flexion (Sparks et al. 2005), creating increased shearing forces over the physeal plate. The posterior slope of the femoral epiphysis also increases these shearing forces acting upon the plate and is a known predictor of SCFE (Barrios et al. 2005; Fishkin et al. 2006).

The physeal plate is substantially weaker against shearing and tensile forces. The extreme range of motion performed during sporting activities and the load applied simultaneously may create unfavourable forces over the physeal plate, leading to injury at physiological loads.

The cam deformity is usually located antero-superiorly on the femoral head (Rakhra et al. 2009) and therefore laterally to the epiphyseal tubercle. It has been claimed that it develops during growth in adolescents and appears to be an extension of the physis (Siebenrock et al. 2011; Siebenrock et al. 2004; Agricola et al. 2014). On microscopic examination, damage in and around the epiphyseal plate was seen primarily laterally to the epiphyseal tubercle after vertical load to failure and repeated sub-failure vertical loading.

The injuries found after cyclical loading were often subtle and might produce only a few symptoms or even be asymptomatic in an individual (Kaeding and Miller 2013).

The findings support the hypothesis that repeated high loads on the adolescent hip can lead to growth disturbance, due to physeal injury and microfractures in the trabecular bone, and consequently the development of cam deformity. The apparent stabilising function of the PFC and the ET might, in some cases, explain a sub-clinical slip of the epiphysis halting and healing again in a slightly changed position.

Using an in-vitro porcine model can be regarded as a limitation when it comes to understanding human hip joint diseases, but many studies of hip biomechanics and hip conditions have used a porcine model, especially in paediatric orthopaedics, (Baranto et al. 2005a; Baranto et al. 2005b; Dodds et al. 2008; Hosalkar et al. 2011; Kishan et al. 2006; Pawaskar et al. 2011; Upasani et al. 2006; Wenger et al. 2007) and, in a study like the present one, it is thought to be appropriate.

During the preparation of the specimens, all the soft tissues were removed. The muscles and ligaments of the hip most definitely play a major role in dynamic hip biomechanics. The conclusions are, however, not affected by this fact, as only semi-static strength is studied.

Macroscopically, the porcine hip is comparable to the human hip, the main difference being a more prominent major trochanter and a shorter and broader femoral neck (Figure 41). Ipsen et al. reported that, in one-year-old pigs, the proximal femoral epiphysis is similar in size to that in adolescent humans and its shear strength is similar to that reported by Chung et al. (Chung et al. 1976; Ipsen et al. 2002). The specimens in the present study are of a size similar to those in a 10-year-old child and the shear strength of the anteriorly loaded specimens was comparable to the values reported by Chung et al. (Chung et al. 1976). The microscopic characteristics of the porcine epiphyseal plate are identical to those of the human epiphyseal plate, with the different epiphyseal growth zones clearly visible (Figure 42).

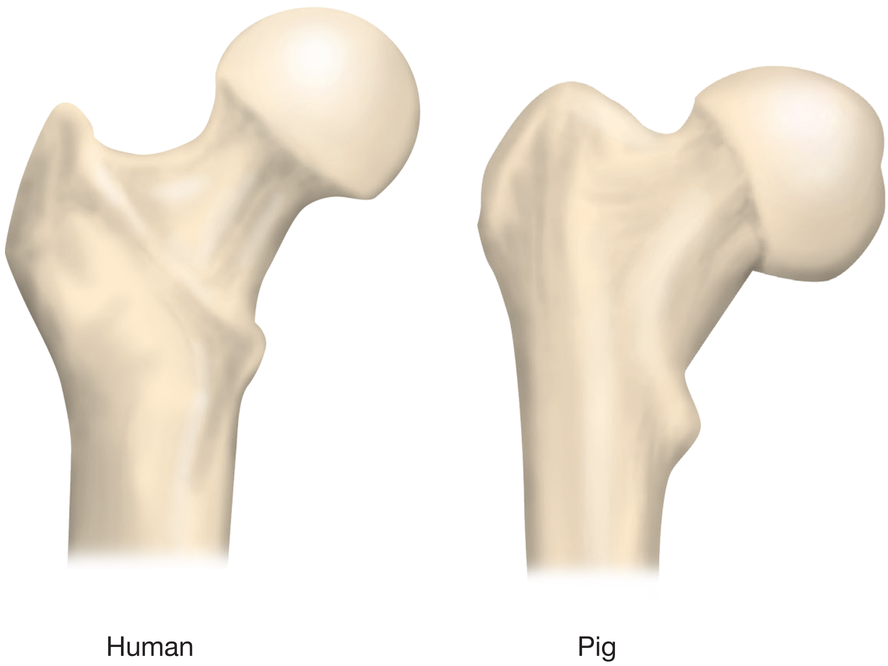

Figure 41 In the porcine hip, the femoral head is aspherical and the femoral neck is shorter and broader than in the human hip.

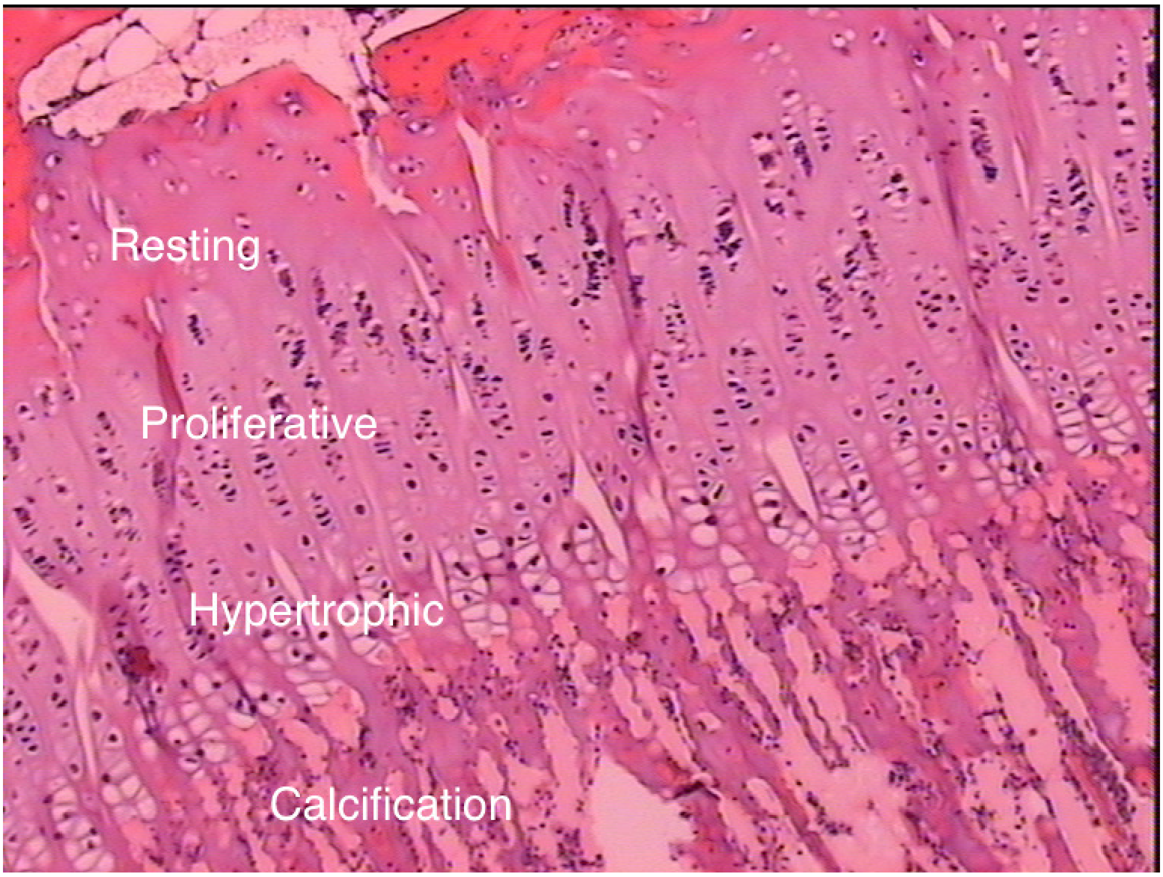

Figure 42 Showing the different zones of the porcine epiphyseal plate.

Relating results from an in-vitro, animal model, to the in-vivo, human condition is and always will be debatable. Porcine models are commonly used in studies of the hip and spine and in paediatric orthopaedics (Baranto et al. 2005a; Baranto et al. 2005b; Dodds et al. 2008; Hosalkar et al. 2011; Jónasson et al. 2014; Kishan et al. 2006; Pawaskar et al. 2011; Thoreson et al. 2010; Upasani et al. 2006; Wenger et al. 2007; Lundin et al. 2000; Karlsson et al. 1998; Kaigle et al. 1998) and are accepted in the literature as appropriate models (Pearce et al. 2007).

MRI of dead tissue has certain limitations and interpreting the findings is therefore difficult. A difference in fluid distribution was noted within the tissue. Mechanical loading of the tissue probably alters the distribution of fluid. With heavier loads, more redistribution of fluid can occur. Differences in signal intensity between loaded specimens and controls were predominantly observed adjacent to the physeal plate, medially to the epiphyseal tubercle. No separations or injuries could be seen in the cartilage and no fractures were observed, probably due to the poor ability of MRI to detect microfractures. These findings are in accordance with those made by Baranto et al. in biomechanical experimental studies of young procine spines (Baranto et al. 2005a; Baranto et al. 2005b). They found only 25% of the physeal plate fractures on MRI compared with 100% on histological examination. Micro-CT with thin slices could perhaps reveal fracture injuries in the skeletal part of the femur. In the present study, fractures were seen on microscopic examination, but the fluid distrubution seen on MRI provides added information on the load distribution in the tissues, showing changes where fractures were not detected.

5. 3. SCORES

The principal findings of these studies were that both the iHOT12-S and the HAGOS-S are valid, reliable and responsive HR-PROs, for patients with FAI, undergoing hip arthroscopy.

During translation and adaptation, the authors carefully followed a standardised process described in the literature. This should make the adapted version highly comparable with the original version. During the evaluation of the adapted version, the authors carefully followed the COSMIN checklist to ensure the assessment of every psychometric property.

With the development of the COSMIN checklist, health-care specialists use a standardised instrument to evaluate the quality of studies measuring PRO instrument properties. The authors have used the COSMIN checklist during the design and reporting of the present study. The checklist was found to be easy to follow, but it does not as yet conclude what constitutes adequate measurement qualities. Criteria proposed in the literature were used during calculations.

Study population

Both scores were developed for young and middle-aged, active patients aged 18-60 years. The HAGOS was developed with patients with hip and groin disability in mind and the iHOT12 for patients undergoing hip arthroscopy. During these studies, 502 patients, some younger and some older (15-75 years), and only patients with FAI undergoing hip arthroscopy were included. Both scores were found to be suitable for this particular patient group.

Reliability

Internal consistency

All HAGOS subscales showed very good homogeneity, with an internal consistency between 0.77 and 0.89, as measured with Cronbach's alpha. The original study showed that Cronbach's alpha lay between 0.79 and 0.93 (Thorborg et al. 2011).

Although factor analysis revealed that the iHOT12-S measures two constructs, Physical Function and Symptoms, the internal consistency of the whole questionnaire was high, with a Cronbach's alpha of 0.89. A Cronbach's alpha of almost 0.90 indicates a high internal correlation, leading to the belief that the iHOT12 could include even fewer items. The original iHOT33 had a Cronbach's alpha of 0.99 and, with just four of the 12 questions on the iHOT12 representing 99% of the variability of the iHOT33, some item redundancy with a high Cronbach's alpha was to be expected (Griffin et al. 2012; Mohtadi et al. 2012). The Cronbach's alpha for the original version of the iHOT12 was not reported.

Test-retest reliability

With an ICC between 0.81 and 0.89 for the six subscales, the test-retest reliability of the HAGOS-S was found to be very good and in agreement with the ICC reported in the original publication (Thorborg et al. 2011).

With an ICC of 0.88 for the average iHOT12-S score, the test-retest reliability was considered good and in agreement with the ICC of 0.89 reported in the original publication (Griffin et al. 2012). Three of the 12 items in the iHOT12-S, however, had an ICC that was somewhat lower than the expected 0.70. Two items had an ICC of 0.68 (items 2 and 5), lying close to the expected 0.70. Item 7 had an ICC of 0.59. This item relates to pain after activity in the last four weeks. It is possible that the patients were less active after a decision relating to hip surgery was made, explaining the difference between the testing and retesting of this item.

Measurement error

The SDC for the six subscales of the HAGOS-S at individual level was at a clinically acceptable level (between 7.8 and 16.1) and the HAGOS-S could therefore be recommended for use in individual patients. A change of 20 points, as used in this study for a clinically relevant change in GPE, can thus also be recommended as a clinically relevant change at individual level in the HAGOS-S. The low SDC values at group level (between 1.5 and 2.7) strongly indicate that the HAGOS-S is very useful for group comparisons.

For the iHOT12-S, the SDC at individual level was high for the different items, but the SDC for the total average score was 17.1, which indicates that a change of 20 points for the total average exceeds the measurement error and may reflect a true change in the individual patient's symptoms. At group level, a change of eight points in any item exceeds the measurement error and is likely to represent a true change in the group's symptoms.

Validity

Construct validity

The factor analysis revealed that the six HAGOS-S subscales had one strong factor per subscale, which is in accordance with the original HAGOS (Thorborg et al. 2011). For the iHOT12-S, finding two factors with an eigenvalue of > 1 was not surprising, given that the original iHOT33 measured four different subscales (symptoms and functional limitations; sports and recreational activities; job-related concerns; social, emotional and lifestyle concerns) and, during the development of the iHOT12, the authors included questions from all the subscales. Looking more closely at the factor analysis, it can be concluded that the iHOT12-S measures two factors: a factor of function and symptoms (questions 2, 3, 4, 5, 8 and 9) and a factor of pain and concern/distraction (questions 1, 6, 7, 10, 11 and 12). Dividing a questionnaire with just 12 items into different subscales would be excessive and make the instrument more complex.

Significant correlations were found between the HAGOS-S subscales and the EQ-5D-S total score, ranging from rs = 0.40 to rs = 0.60. Significant correlations were found between the HAGOS-S subscales and EQ-5D-S subscales, ranging from rs = -0.10 to rs = -0.57. As hypothesised, somewhat lower correlations were found for the EQ-5D-S subscales of self-care (average rs = -0.19) and anxiety/depression (average rs = -0.29) compared with the subscales of mobility, usual activities and pain/discomfort (average rs=-0.47, -0.35, -0.40 respectively). The latter three subscales thus correlated more highly with the HAGOS-S than hypothesised. Correlations between the iHOT12-S and EQ-5D were as expected – good for the mobility, usual activities and pain/discomfort subscales. Interestingly, a higher correlation than expected was found with the anxiety/depression subscale (Spearman r=0.34), indicating a larger psychological factor than hypothesised. Significant correlations were also found between the HAGOS-S and the iHOT12-S average score, ranging from rs = 0.37 to rs = 0.68, which was as hypothesised, apart from the HAGOS-S subscale of physical activity, where the correlations were lower than expected.

Responsiveness

In order to express the patients' clinical change in hip status, it was decided to use a GPE-VAS to determine whether significant changes in patient symptoms had occurred. A change of 20 mm or more was considered clinically relevant. Minimal important changes on a pain VAS have been found to range from 13 to 30 mm [3,5,10,12].

The GPE score correlated strongly with the HAGOS-S subscales, ranging from rs = 0.40 to rs =0.68. Moderate correlations were found between the iHOT12-S individual items and the GPE, but the total average score correlated strongly with rs =0.52.

As hypothesised, the SRM and ES were lower for patients reporting little clinical change in hip status and higher for patients reporting a larger clinical change in hip status, indicating good responsiveness of both the HAGOS-S and iHOT12-S.

Clinically, most of the patients had recovered well (although not completely) after four months. Larger ES and SRM can thus be expected at four months compared with 12 months, for example.

Interpretability

Floor and ceiling effects were detected in the HAGOS-S. At baseline, 31.5% of the patients obtained the lowest score on the subscale of participation in physical activities. The two questions in the subscale ask: Are you able to participate in your preferred physical activities for as long as you would like? and Are you able to participate in your preferred physical activities at your normal performance level? with the alternatives: Always – Often – Sometimes – Rarely – Never. It is not surprising that many patients with hip and/or groin disability choose the alternative never. At four months, however, fewer patients (21.9%) chose the alternative never. Future studies will show whether this apparent floor effect is present in the long term. At four months, there is a ceiling effect (16.9%) in the function in daily living subscale, indicating that the sensitivity of this subscale can be limited in this patient population. Floor and ceiling effects were not detected in the iHOT12-S. The iHOT12-S is therefore able to measure both improvement and deterioration over time in the study population.

When developing the COSMIN checklist, no consensus was reached about the method that should be used to measure the MIC (Mokkink et al. 2010a). The MIC is supposed to measure the minimal change in score that the patient regards as important. The rule of thumb that the MIC can be estimated as half an SD was proposed by Norman et al. (Norman et al. 2003) and, as long as no consensus is reached on the methods by which the MIC should be measured, the authors find this simple rule as good as any other. Applying this rule to the data gave an MIC of 9 to 17 for the HAGOS-S subscales and 9 to 16 for the individual items and 9 for the total average score at baseline and the four-month follow-up.

The SDC at individual level is slightly higher than the MIC for some of the HAGOS subscales and considerably higher than the individual items on the iHOT12-S. The total average score of the iHOT12-S gives a good indication of how the individual patient is doing; however, results at individual level should be interpreted with caution. At group level, each of the six HAGOS subscales and the individual items and the total average score of the iHOT12-S can be used independently to identify changes in certain aspects of patients' symptoms.

The present data are in agreement to a very large extent with the original studies, in terms of reliability, validity and responsiveness (Thorborg et al. 2011; Griffin et al. 2012). In a small subpopulation of 50 patients undergoing hip arthroscopic surgery, Kemp et al. recently evaluated the reliability, validity, responsiveness and interpretability of five HR-PROs, including the HAGOS and the iHOT33 (Kemp et al. 2013). They concluded that some of the psychometric properties of the HAGOS were reduced, based on the fact that the HAGOS subscale related to activities of daily living showed a ceiling effect, which is in agreement with the present study. It is, however, not surprising that, as patients get better, they become symptom free in activities of daily living before they are symptom free in sports-related activities. The iHOT33 did not show any signs of floor or ceiling effects, but the use of a single aggregate score can be criticised as it limits the ability to discriminate between different domains of importance to patients.

In a recent study, Hinman et al. searched for the best HR-PRO for 30 patients with femoroacetabular impingement in terms of test-retest reliability (Hinman et al. 2014). They were able to demonstrate that the majority of the questionnaires, including the HAGOS and iHOT33, were reliable and precise enough to use at group level, which is in agreement with the present studies.
In a systematic review of PRO questionnaires for young and middle-aged patients with hip and groin disability, the authors concluded that the HAGOS, iHOT33 and iHOT12 could be recommended in the assessment of that patient group (Thorborg et al. 2015). They also concluded that the methodological quality of the existing studies varied and could be considerably improved.

5. 4. GENERAL DISCUSSION

With increasing participation in sports and recreational activities, symptoms of pain and stiffness of the hip joint are common. These symptoms are often attributed to FAI and hip arthroscopy has become a standard procedure in this group of patients. The symptoms of FAI are more common in athletes than in the general population, but the presence of radiographic variations of FAI are often found in the asymptomatic individual. Moreover, symptoms similar to FAI can also occur without these characteristic variations being found on radiographs. It is therefore important that the diagnosis and treatment are based on solid scientific grounds.

Although previous studies have shown that the radiographic changes of FAI are more common in athletes and active patients, this was not shown in the present study. Based on the findings in the clinical study, it is not possible to state whether the radiographic changes of FAI are acquired because of high load training during the athlete’s growth or whether the symptoms of FAI develop because of the increased load in the presence of the radiographic changes.

In the biomechanical studies, injuries seen in and around the growth plates are likely to affect growth. These injuries could therefore explain the presence of cam deformity in the athlete.

Because of the uncertain cause-and-effect relationship between symptoms and radiographic changes of FAI, it is important to develop valid and reliable instruments to measure the result of different treatments. Further clinical studies comparing the symptoms and radiographic changes found in patients and the outcomes of different treatments are needed. The PROMs adapted and validated in the present thesis are an important factor for the quality of future research.

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CONCLUSIONS

CONCLU-SIONS

6. CONCLUSIONS

• Although cam morphology was not more pronounced in the athletes, they had significantly lower ROM and more pain on FADDIR and FABER tests. These differences could be explained by the occurrence of osteoarthritic (OA) changes in the athlete group.

• The occurrence of cam morphology in the non-athlete group was higher than previously reported.

• Cam morphology is connected to degenerative osteoarthritis. The effect appears to be larger when the cam is placed more superiorly on the femoral head-neck junction.

• The epiphyseal plate is the weakest point in the porcine proximal femur.

• The epiphyseal plate is weakest against shearing and tensile forces but strongest against compressive forces.

• The PFC and the epiphyseal tubercle appear to have a stabilising function for the porcine proximal femoral epiphysis.

• Injuries seen in and around the epiphyseal plate in the porcine proximal femur after cyclical loading are likely to cause growth disturbances that could lead to the development of cam morphology.

• The HAGOS-S and the iHOT12-S are valid and reliable instruments available for use in research and clinically with young and middle-aged active patients with hip and groin disability and undergoing hip arthroscopy.

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FUTURE PERSPECTIVES

FUTURE PERSPECTIVES

7. FUTURE PERSPECTIVES

The aetiology of the cam deformity is unclear. More research is needed on the effect intense training among elite adolescent athletes has on their skeletal growth. Are there differences between different sports or different parts of the world? If the high load imposed upon the growing elite athlete's body causes growth disturbances, can these disturbances be avoided by reducing the training and competition intensity when the athlete is growing? At which stage in the athlete's growth is the risk of growth disturbances largest? Is it even practical, given the pressure from parents, trainers and clubs, to change the type of training or reduce the amount of training among these potential future sports stars and will it help in preventing the development of cam deformity? All these questions and more remain to be answered.

The use of standardised HR-PROMs will help to increase our understanding of hip and groin disorders. The symptoms of FAI can be present in patients without apparent radiographic changes and radiographic changes can be present without symptoms. There is a need for an improved clinical understanding, diagnostic tests and radiographic investigations to help with the diagnosis of the patient presenting with hip and groin pain. This will lead to improved diagnostics and stronger indications for treatment.

The risk of developing symptoms of FAI in the presence of radiographic changes needs to be investigated. Are certain radiographic variations more likely to cause future symptoms and lead to osteoarthritis? Can the development of symptoms and osteoarthritis be delayed or even stopped by early intervention? Should different subgroups of patients be treated differently depending on activity levels, gender, age or degree of arthritic changes?

As the treatment of FAI and hip arthroscopy is a relatively new procedure, more research is needed on the outcome of this procedure, together with comparisons with different treatment alternatives. Different surgeons perform the procedure differently. The standardisation of the procedure is needed to be able to compare outcomes.

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APPENDIX

HAGOS
Frågeformulär om höft- och/eller ljumskproblem

HAGOS

Frågeformulär om höft- och/eller ljumskproblem

Datum: ________________________ CPR nr: ________________________

Namn: ____

VÄGLEDNING: Detta frågeformulär innehåller frågor om hur din höft och/eller ljumske fungerar. Du skall ange hur din höft och/eller ljumske har fungerat under **den senaste veckan**. Svaren skall hjälpa oss att kunna förstå hur du har det och hur bra du klarar dig i vardagen.

Du skall besvara frågorna genom att kryssa för det alternativ som passar dig bäst. Du skall endast ange ett kryss för varje fråga. Du skall svara på alla frågorna. Om en fråga inte gäller dig eller om du inte upplevt besväret under den senaste veckan, så ange det alternativ som passar bäst in och som du känner dig mest nöjd med.

Symptom

Tänk på de **symptom** och besvär du har haft i din höft och/eller ljumske under **den senaste veckan** när du svarar på följande frågor.

S1 Har du malande/obehag i höften och/eller ljumsken?

Aldrig	Sällan	Ibland	Ofta	Alltid
☐	☐	☐	☐	☐

S2 Har du hört klickande eller andra ljud från höften och/eller ljumsken?

Aldrig	Sällan	Ibland	Ofta	Hela tiden
☐	☐	☐	☐	☐

S3 Har du problem med att få benen långt ut åt sidan?

Inga	Lite	Måttliga	Stora	Mycket stora
☐	☐	☐	☐	☐

S4 Har du problem med att ta steget fullt ut när du går?

Inga	Lite	Måttliga	Stora	Mycket stora
☐	☐	☐	☐	☐

S5 Får du plötsliga stickande/pirrande förnimmelser i höften och/eller ljumsken?

Aldrig	Sällan	Ibland	Ofta	Hela tiden
☐	☐	☐	☐	☐

Översatt och kulturanpassat till svenska av Roland Thomeé*, Pall Sigurgeir Jonasson*, Mikael Sansone*, Kristian Thorborg¤ och Jon Karlsson*.
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Stelhet

Följande frågor handlar om **stelhet i höften och/eller ljumsken.** Stelhet medför besvär att komma igång eller ett ökat motstånd när du böjer höften och/eller ljumsken. **Ange i hur stor grad du har upplevt stelhet i höften och/eller ljumsken under den senaste veckan.**

S6 Hur stel är du i din höft och/eller ljumske när du just har vaknat på morgonen?

Inte alls	Lite	Måttligt	Mycket	Extremt
☐	☐	☐	☐	☐

S7 Hur stel är du i din höft och/eller ljumske senare på dagen, efter att du har suttit eller legat och vilat dig?

Inte alls	Lite	Måttligt	Mycket	Extremt
☐	☐	☐	☐	☐

Smärtor

P1 Hur ofta har du ont i höften och/eller ljumsken?

Aldrig	Varje månad	Varje vecka	Varje dag	Alltid
☐	☐	☐	☐	☐

P2 Hur ofta har du ont på andra ställen än i höften och/eller ljumsken som du tycker hänger ihop med dina höft- och/eller ljumskproblem?

Aldrig	Varje månad	Varje vecka	Varje dag	Alltid
☐	☐	☐	☐	☐

Följande frågor handlar om hur ofta du haft smärta i höften och/eller ljumsken under **den senaste veckan. Ange graden av höft- och/eller ljumsksmärta du har upplevt i följande situationer.**

P3 Sträcka ut höften helt och hållet

Ingen	Lätt	Måttlig	Svår	Mycket svår
☐	☐	☐	☐	☐

P4 Böja höften helt och hållet

Ingen	Lätt	Måttlig	Svår	Mycket svår
☐	☐	☐	☐	☐

P5 Gå upp- eller nedför trappor

Ingen	Lätt	Måttlig	Svår	Mycket svår
☐	☐	☐	☐	☐

P6 Om natten när du ligger ned (smärtor som förstör din sömn)

Ingen	Lätt	Måttlig	Svår	Mycket svår
☐	☐	☐	☐	☐

P7 Sitta eller ligga

Ingen	Lätt	Måttlig	Svår	Mycket svår
☐	☐	☐	☐	☐

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Följande frågor handlar om hur ofta du har haft smärta i höften och/eller ljumsken under **den senaste veckan. Ange graden av höft- och/eller ljumsksmärta du har upplevt i följande situationer.**

P8 Stående

Ingen	Lätt	Måttlig	Svår	Mycket svår
☐	☐	☐	☐	☐

P9 Gå på hårt underlag, på asfalt eller sten

Ingen	Lätt	Måttlig	Svår	Mycket svår
☐	☐	☐	☐	☐

P10 Gå på ojämnt underlag

Ingen	Lätt	Måttlig	Svår	Mycket svår
☐	☐	☐	☐	☐

Fysisk funktion, dagliga aktiviteter

Följande frågor handlar om din fysiska funktion. **Ange graden av besvär du har haft i följande situationer under den senaste veckan, på grund av din höft och/eller ljumske.**

A1 Gå uppför trappor

Inga	Lätta	Måttliga	Stora	Mycket stora
☐	☐	☐	☐	☐

A2 Böja dig ner, tex för att plocka upp något från golvet

Inga	Lätta	Måttliga	Stora	Mycket stora
☐	☐	☐	☐	☐

A3 Kliva i/ur bil

Inga	Lätta	Måttliga	Stora	Mycket stora
☐	☐	☐	☐	☐

A4 Ligga i sängen (vända dig eller hålla höften i samma läge under lång tid)

Inga	Lätta	Måttliga	Stora	Mycket stora
☐	☐	☐	☐	☐

A5 Utföra tungt hushållsarbete (tvätta golv, dammsuga, bära drickabackar och liknande)

Inga	Lätta	Måttliga	Stora	Mycket stora
☐	☐	☐	☐	☐

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Funktion, sport och fritid

Följande frågor handlar om din fysiska förmåga. Du skall svara på ALLA frågor. Om en fråga inte gäller dig eller om du inte upplevt besväret under den senaste veckan, så ange det alternativ som passar bäst in och som du känner dig mest nöjd med. **Ange vilken grad av besvär du har haft i följande aktiviteter under den senaste veckan, på grund av problem med din höft och/eller ljumske.**

SP1 Sitta på huk

Inga	Lätta	Måttliga	Stora	Mycket stora
☐	☐	☐	☐	☐

SP2 Springa

Inga	Lätta	Måttliga	Stora	Mycket stora
☐	☐	☐	☐	☐

SP3 Vrida/snurra kroppen när du står på benet

Inga	Lätta	Måttliga	Stora	Mycket stora
☐	☐	☐	☐	☐

SP4 Gå på ojämnt underlag

Inga	Lätta	Måttliga	Stora	Mycket stora
☐	☐	☐	☐	☐

SP5 Springa så snabbt du kan

Inga	Lätta	Måttliga	Stora	Mycket stora
☐	☐	☐	☐	☐

SP6 Föra benet framåt kraftigt och/eller till sidan, exempelvis som vid en spark, skridskosteg eller liknande

Inga	Lätta	Måttliga	Stora	Mycket stora
☐	☐	☐	☐	☐

SP7 Plötsliga, explosiva rörelser som involverar snabba fotrörelser, exempelvis accelerationer, uppbromsningar, riktningsförändringar eller liknande

Inga	Lätta	Måttliga	Stora	Mycket stora
☐	☐	☐	☐	☐

SP8 Situationer där benet rör sig helt ut i ytterläge (med ytterläge menas så långt ut från kroppen som möjligt)

Inga	Lätta	Måttliga	Stora	Mycket stora
☐	☐	☐	☐	☐

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Delta i fysisk aktivitet

Följande frågor handlar om din förmåga att delta i fysiska aktiviteter. Med fysiska aktiviteter menas idrottsaktiviteter, men även andra aktiviteter, där man blir lätt andfådd. Ange i vilken grad din förmåga att delta i önskade fysiska aktiviteter har varit påverkade under senaste veckan, på grund av dina problem med din höft och/eller ljumske.

PA1 Kan du delta i önskade fysiska aktiviteter så länge du vill?

Alltid	Ofta	Ibland	Sällan	Aldrig
☐	☐	☐	☐	☐

PA2 Kan du delta i önskade fysiska aktiviteter på din normala prestationsnivå?

Alltid	Ofta	Ibland	Sällan	Aldrig
☐	☐	☐	☐	☐

Livskvalitet

Q1 Hur ofta blir du påmind om dina problem med höften och/eller ljumsken?

Aldrig	Varje månad	Varje vecka	Varje dag	Alltid
☐	☐	☐	☐	☐

Q2 Har du ändrat ditt sätt att leva för att undgå att påfresta höften och/eller ljumsken?

Inget alls	Något	Måttligt	I stor utsträckning	Totalt
☐	☐	☐	☐	☐

Q3 Hur stora problem har du generellt med din höft och/eller ljumske?

Inga	Lätta	Måttliga	Stora	Mycket stora
☐	☐	☐	☐	☐

Q4 Påverkar dina problem med höften och/eller ljumsken ditt humör i en negativ riktning?

Aldrig	Sällan	Ibland	Ofta	Alltid
☐	☐	☐	☐	☐

Q5 Känner du dig begränsad p.g.a. problem med din höft och/eller ljumske?

Aldrig	Sällan	Ibland	Ofta	Alltid
☐	☐	☐	☐	☐

Tack för att du har besvarat Alla frågorna!

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APPENDIX

iHOT12
Formulär om livskvalité hos unga aktiva människor med höftproblem

iHOT[12]

INTERNATIONAL
HIP OUTCOME TOOL

NAMN: ....

PERSONNR: ....

DAGENS DATUM: ....

VILKEN HÖFT HANDLAR DETTA FORMULÄR OM?
Om vi bett dig att ge svar om en specifik höft, markera den.
Annars markera den höft som ger dig mest besvär.

◯ **Vänster**
◯ **Höger**

FORMULÄR OM LIVSKVALITÉ HOS UNGA AKTIVA MÄNNISKOR MED HÖFTPROBLEM

INSTRUKTIONER

- Dessa frågor handlar om de besvär som du kan uppleva i din höft, hur dessa besvär påverkar ditt liv och de känslor du känner som följd av dessa besvär.
- Vänligen ange svårighetsgraden av dina höftbesvär genom att markera linjen med ett streck nedanför varje fråga
  - » Om du markerar längst ut till vänster betyder det att du känner dig påtagligt begränsad. Till exempel:

    PÅTAGLIGT BEGRÄNSAD ⟋———————————————— INGA PROBLEM ALLS

  - » Om du markerar längst ut till höger betyder det att du inte har några problem alls med din höft. Till exempel:

    PÅTAGLIGT BEGRÄNSAD ————————————————⟋ INGA PROBLEM ALLS

  - » Om markeringen placeras mitt på linjen betyder det att du är måttligt besvärad, eller med andra ord, mitt emellan 'påtagligt begränsad' och 'inga problem alls'. Det är viktigt att du markerar ända ut i kanten av linjen om det är ytterligheten som bäst beskriver din situation.

TIPS Om du inte utför en aktivitet, föreställ dig hur det skulle kännas i din höft om du var tvungen att utföra aktiviteten.

- Vänligen låt dina svar beskriva den typiska situationen senaste månaden.

....

F1 Totalt sett, hur mycket smärta har du i din höft/ljumske?

EXTREM SMÄRTA ———————————————— INGEN SMÄRTA ALLS

....

F2 Hur svårt är det för dig att ta dig ner på och upp från golvet/marken?

EXTREMT SVÅRT ———————————————— INTE SVÅRT ALLS

....

F3 Hur svårt är det för dig att gå långa distanser?

EXTREMT SVÅRT ———————————————— INTE SVÅRT ALLS

International Hip Outcome Tool 12 (iHOT12) – svensk version 1.0. 2011
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F4 Hur mycket besvär har du av krasningar, upphakningar eller klickande i din höft?

PÅTAGLIGA BESVÄR ______________________ INGA BESVÄR ALLS

F5 Hur mycket besvär har du av att knuffa, dra, lyfta eller bära tunga föremål?

PÅTAGLIGA BESVÄR ______________________ INGA BESVÄR ALLS

F6 Hur oroad är du över riktningsförändringar när du idrottar eller motionerar?

EXTREMT OROAD ______________________ INTE OROAD ALLS

F7 Hur mycket smärta har du i din höft *efter* aktivitet?

EXTREM SMÄRTA ______________________ INGEN SMÄRTA ALLS

F8 Hur oroad är du över att lyfta upp och bära barn på grund av din höft?

EXTREMT OROAD ______________________ INTE OROAD ALLS

F9 Hur mycket besvär har du med sexuella aktiviteter på grund av din höft?

☐ Detta är inte relevant för mig

PÅTAGLIGA BESVÄR ______________________ INGA BESVÄR ALLS

F10 Hur mycket tid är du medveten om dina besvär med din höft?

KONSTANT MEDVETEN ______________________ INTE MEDVETEN ALLS

F11 Hur oroad är du över din möjlighet att upprätthålla din önskade fysiska nivå?

EXTREMT OROAD ______________________ INTE OROAD ALLS

F12 Hur distraherande/störande är dina höftproblem?

EXTREMT DISTRAHERANDE/ STÖRANDE ______________________ INTE ALLS DISTRAHERANDE/ STÖRANDE

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