Universidade de Aveiro Secção Autónoma de Ciências da Saúde
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Factores Biomecânicos e estrutura do *gluteus medius* na artrose da anca: Indicadores clínicos e radiográficos

Biomechanical factors and gluteus medius structure in hip osteoarthritis: clinical and radiographic findings

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Dissertação apresentada à Universidade de Aveiro para cumprimento dos requisitos necessários à obtenção do grau de Doutor em Ciências Biomédicas, realizada sob a orientação científica do Professor José Alberto Duarte, Professor Catedrático da Faculdade de Desporto da Universidade do Porto e do Professor Francisco Amado, Professor Auxiliar do Departamento de Química da Universidade de Aveiro.

This study was supported by a grant for health research ("Projectos I&DT em Ciências e Tecnologias da Saúde – 2002") conceded by the University of Aveiro.

Agradecimentos

Este trabalho só foi possível com o apoio e colaboração de numerosas pessoas a quem quero agradecer e das quais destaco: O Professor José Alberto Duarte, que aceitou orientar esta tese e cujo suporte e entusiasmo em todas as etapas da mesma foram fundamentais para a sua conclusão. O Professor Francisco Amado, pela sua colaboração, incentivo e total disponibilidade ao longo do desenvolvimento do estudo. A Professora Helena Nazaré, Reitora da Universidade de Aveiro e o Professor Nelson Rocha, Pró-Reitor para a Saúde, os grandes “responsáveis” por todo o processo que levou à minha decisão de elaborar este trabalho; o seu apoio e estímulo constantes foram essenciais; desde o nosso primeiro encontro há cerca de 6 anos, que fiquei convicto de que a Universidade de Aveiro não só tinha um projecto ambicioso para as Ciências da Saúde, mas acima de tudo tinha as pessoas certas para o liderar. O Prof. Hans Joachim Appell pelo seu incentivo e colaboração nas várias etapas deste trabalho. Os Médicos dos Serviços de Ortopedia e de Medicina Física e de Reabilitação do Hospital Infante D. Pedro, com particular destaque para os seus directores Dr. António Meireles e Drª Acilda Mendes, pela sua colaboração e disponibilidade para garantir todos os meios necessários à execução dos estudos. A Mestre Sandra Calado e todos os Técnicos bem como o Director do Serviço de Anatomia Patológica do Hospital Infante D. Pedro, pela sua colaboração no tratamento das amostras de biópsia muscular. A Drª Alexandra Ferreira, o Mestre Luís Sancho, a Professora Joana Silva, a Terapeuta Gabriela Oliveira, o Dr. José Oliveira e o Dr. Carlos Neri pela sua generosa colaboração. De forma particular a Família, que é o meu reduto, a minha verdadeira “circunstância” sem a qual o “Eu” e todo o seu trabalho não teria qualquer sentido.

o júri

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palavras-chave

Osteoartrose, glúteo médio, atrofia muscular, amplitude de movimento, biomecânica da anca, função abdutora, Índice de Lequesne, Índice de Kellgren, osteófitos, entrelinha articular, prótese total da anca

resumo

O presente trabalho teve como objectivo o estudo da relação entre a função, os factores biomecânicos e o grau das alterações radiográficas em doentes com diferentes graus de osteoartrose (OA) da anca. Foi efectuado protocolo de avaliação clínica e radiográfica a ambas as ancas de 65 doentes a aguardar cirurgia para colocação de prótese total da anca (PTA). Durante a cirurgia foram efectuadas, em todos os doentes, biópsias do músculo glúteo médio (GM) ipsilateral. A reavaliação 6 meses após cirurgia foi efectuada em 18 destes doentes. Utilizando a soma das medidas da entrelinha articular (EA) efectuadas em ambas as ancas e em 3 pontos da região de suporte de carga (lateral, superior e axial), obteve-se uma correlação mais forte com a função das ancas medida pelo índice de Lequesne ($r=0.67$, $p<0.05$), relativamente a qualquer valor individual incluindo a EA mínima; esta correlação foi também mais marcada com todas as amplitudes articulares com destaque para a abdução ($r=0.60$, $p<0.05$) e a rotação externa ($r=0.57$, $p<0.05$). O comprimento dos osteófitos acetabulares superiores (OAS) teve uma correlação positiva significativa com o score de dor do índice de Lequesne ($r=0.38$, $p<0.05$) e negativa com a abdução máxima ($r=-0.50$, $p<0.05$); a abdução teve a correlação mais forte com o ângulo de abdução livre radiográfico ($r=0.60$, $p<0.05$), situado entre o colo do fémur e a extremidade dos OAS e com vértice no centro da cabeça do fémur. Após mais de 6 meses da cirurgia, a anca operada apresentou correlação significativa dos parâmetros radiográficos (braço de alavanca dos músculos abdutores e índice disfuncional) com o tempo de permanência na abdução activa máxima (respectivamente $r=0.61$ e $r=0.63$; $p<0.05$). A soma das 3 medidas da EA teve correlação significativa com a área média das fibras do GM, sendo esta mais marcada com a EA da anca oposta ($r=0.49$, $p<0.05$) do que da anca a aguardar cirurgia ($r=0.32$, $p<0.05$). Este trabalho sugere que, nos doentes submetidos a PTA, o braço de alavanca abdutor é determinante nos resultados funcionais pós-cirurgia. A soma dos valores da EA em 3 pontos estandardizados da área de suporte de carga tem a maior correlação com o grau de evolução da OA da anca. Os OAS limitam a amplitude da abdução da anca. A atrofia do GM correlaciona-se com a medida da EA de ambas as ancas. O défice de força dos abdutores pode condicionar o desgaste articular da anca contralateral. Estes resultados apontam para a importância do reforço dos músculos abdutores e da adopção de estratégias que diminuam a sobrecarga mecânica articular de forma a prevenir e limitar a evolução da OA da anca.

keywords

Osteoarthritis, gluteus medius, muscle atrophy, range of motion, hip biomechanics, abductor function, Lequesne Index, Kellgren Index, osteophytes, joint space width, total hip replacement

abstract

This study investigated the possible relationship between function, biomechanical factors and radiographic degenerative changes in patients with several degrees of hip osteoarthritis (OA). A clinical and radiographic evaluation protocol was performed on both hips of 65 patients awaiting surgery for total hip replacement (THR). During surgery a biopsy of the ipsilateral gluteus medius (GM) muscle was done in all patients. Post-surgery follow up was performed in 18 patients. The sum of radiographic joint space width (JSW) made in three points of the load bearing region (lateral, superior and axial) in both hips, evidenced a stronger correlation with hip function measured by the Lequesne Index ($r=0.67$, $p<0.05$), when compared to any individual value, including minimum JSW. This correlation was also stronger with all joint ranges, particularly abduction ($r=0.60$, $p<0.05$) and external rotation ($r=0.57$, $p<0.05$). Cranial acetabular osteophytes (CAO) length correlated positively and significantly with pain score of Lequesne Index ($r=0.38$, $p<0.05$) and negatively with maximal abduction ($r=-0.50$, $p<0.05$); abduction had the strongest correlation with the radiographic abduction free angle ($r=0.60$, $p<0.05$), located between the femoral neck and CAO lateral extremity, and with the apex at the centre of the femoral head. Follow up conducted over 6 months showed a significant correlation between post-surgery radiographic parameters (abductor muscle lever arm and hip dysfunction index) and time of maximal active abduction ($r=0.61$, $r=0.63$ and $p<0.05$, respectively). The sum of the three measures of hip JSW was correlated significantly with the mean GM fibre area. This correlation was stronger with the JSW of contralateral hip ($r=0.49$, $p<0.05$) than in hip awaiting surgery ($r=0.32$, $p<0.05$). This study suggests that in THR the abductor lever arm length is critical to post-surgery functional results. The sum of three standard measurements of JSW in hip weight-bearing area has the strongest correlation with the clinical development of hip OA; the hip abduction range of motion is limited by CAO; the GM atrophy correlates with JSW of both hips. The abductor weakness leads to the increase of mechanical impact during load shift, which may determine the wearing-off of the contralateral hip. Therefore, the present results point to the importance of reinforcing the abductor muscles, together with strategies to decrease the joint mechanical overload, in order to prevent and limit the evolution of hip OA.

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LIST OF ABBREVIATONS

ACR	American College of Rheumatology
AP	Anteroposterior
BMI	Body mass index
CA	Coxarthrosis
CAO	Cranial acetabular osteophytes
DI	Dysfunction Index
FA	Free Angle
GM	Gluteus Medius
IPH	Infante D. Pedro Hospital
JSW	Joint Space Width
MHC	Myosin heavy chains
MJS	Minimal joint space
OA	Osteoarthritis
ROM	Range of motion
ROPM	Range of passive motion
SPSS	Statistical Package for the Social Sciences
WOMAC	Western Ontario and McMaster Universities Osteoarthritis Index

General Introduction

Osteoarthritis (OA) is the most common joint pathology and has a multifactorial, complex and still relatively unknown etiology (Dieppe, 1984, 1991, 1997; Hart and Spector, 1995a; Altman, 1997; Altman et al., 2000; Felson et al., 2000; Doherty and Dougados, 2001; Hunter and Felson, 2006). In particular the hip and knee OA develop with functional limitations and reduced quality of life associated to their clinical signs and symptoms, such as pain, stiffness and periarticular muscle strength deficit (Cooper et al., 1996; Oberg and Oberg, 1996; Hopman-Rock et al., 1997; Felson and Zhang, 1998; Doherty and Dougados, 2001; Arokoski et al., 2004).

Hip OA (also named coxarthrosis) has a great social, economic and functional impact and is considered a major public health problem in developed countries (Klippell and Dieppe, 1997; Murray and Lopez, 1997; The Consensus Document, 1998; Yelin, 1998; Felson and Zhang, 1998; Felson et al., 2000); its prevalence increases with age (Lawrence et al., 1966; Danielsson et al., 1984; Hamerman, 1993) reaching 3% to 6% in adult caucasian population (Heliövaara et al., 1993; Hoaglund et al., 1995; Felson and Zhang, 1998; Hoaglund and Steinbach, 2001). Unlike the knee OA, the hip OA has been relatively forgotten in basic biomechanical investigation and in its potential clinical implications (Sun et al., 1997; Robertson et al., 2003). However, both personal (pain and disability) and socioeconomical (job absences, related surgeries and hospitalisation days) hip OA repercussions (Carr, 1999; Brauer et al., 2005; Gupta et al., 2005) seem to constitute important reasons to improve the knowledge related to this pathology.

The study of the radiographic and functional parameters and their correlations to hip OA clinical research may lead to a better diagnosis and treatment and to a better understanding of the factors underlying this pathology. Joint space narrowing, subchondral sclerosis, osteophyte and subchondral cyst formation are the main radiological OA features used to assess OA severity in global classification indexes, being Kellgren & Lawrence's Index (Kellgren and Lawrence, 1957) the better known. According to the American College of Rheumatology (ACR), the clinical criteria to define OA consists of hip pain in most days of the prior month and degenerative joint changes evident in radiographs (Altman et al., 1991); the format of the ACR classification also includes clinical criteria alone, with hip pain and range of motion (ROM) limitations in internal rotation and flexion (Altman et al., 1991). In clinical practice, the diagnosis and grading of severity of hip OA is based mainly on the narrowing of the joint space width (JSW) or global radiographic indexes such as the Kellgren's. However, in hips without radiographic changes and with OA symptoms, a significant percentage of degenerative arthroscopic alterations can be found (Santori and Villar, 1999) suggesting that the radiographic features have a low sensitivity to detect joint damage before it becomes extensive (Altman, 1995; Dieppe, 1995).

The functional evaluation of the osteoarthritic hip is frequently assessed using global indexes aiming to quantify a set of items related to pain, stiffness or functional impairments, being the Lequesne Index (Lequesne et al., 1987) and WOMAC (Bellamy et al., 1988; McConnel et al., 2001) the most frequently used; in addition, ROM and functional evaluation of periarticular muscles must be included in hip examination (Klippell and Dieppe, 1997). Although the ROM can be considered an indicator of joint stiffness, a commonly standard for major ROM deficits of the OA hip joint is actually absent; this situation may result from the great variability in normal hip ROM among healthy subjects (Allander et al., 1974; Boone and Azen, 1979; Roaas and Andersson, 1982; Svenningsen et al., 1984; Roach et al., 1991; Greene and Heckman, 1994; Escalante et al., 1999) and also from the different techniques used to assess joint ROM (American Academy of Orthopaedic Surgeons, 1966; Stratford et al., 1984; Gajdosik and Bohannon, 1987; Greene and Heckman, 1994). On the other hand, the methodology commonly used to assess functional repercussions of hip OA is static and poorly related to the complex dynamics of human activities

(Arokoski et al., 2004). These multiple variables and methods to measure physical function and disability of hip OA patients are a great problem in clinical research, needing a standardized methodology. Moreover, the hip disability must be considered according to the International Classification of Functioning, Disability and Health (ICF) as impairments of articular function and structure, which limit performance activities and restrict daily life situations (World Health Organisation, 2001).

The hip is a ball-and-socket joint and forms a functional unit consisting of bones, cartilage, synovium and capsule with blood, lymphatic and nerve supply and is involved by burse, ligaments and muscles (Vilensky, 1998; Dewire and Einhorn, 2001); the OA, often known as a degenerative "wear and tear" disease of articular cartilage (Dieppe, 1984, 1999), seems to affect all these tissues (Vilensky, 1998; Felson et al., 2000; Hurley, 2002; Hunter and Felson, 2006). It has been assumed that hip OA would result from an imbalance between the mechanical efforts, to which the hip is subjected, and osteo-cartilagineous tissue resilience and repair capacity. (Tanaka et al., 1998; Sandell and Aigner, 2001). Thus, both systemic and local biomechanical factors interfere with OA's pathophysiology (Felson et al., 2000; Hunter and Felson, 2006). Among local biomechanical factors, the strength deficits associated to disuse atrophy caused by pain (O'Reilly et al., 1997; O'Reilly et al., 1998; Hurley, 1999; Felson et al., 2000) and other periarticular muscle alterations (Sirca and Susec-Michieli, 1980; Sims, 1999; Howell et al., 2001; Sims et al., 2002) have been referred; even so, longitudinal studies in knee OA suggest that quadriceps strength deficits might not only result from pain, but may actually precede radiographic OA signs, thus representing a risk factor for joint degeneration, presumably due to a reduced stability and decreased mechanical shock absorption ability (Slemenda et al., 1997, 1998; Hurley, 1999).

In the knee joint, quadriceps weakness is a better determinant of pain and disability than any radiographic changes (Lankhorst et al., 1985; Hurley and Newham, 1993; Madsen et al., 1995). In the hip joint, few studies have assessed the relationship between muscular function and OA (Jandric, 1998; Arokoski et al., 2002), although strength deficit of periarticular muscles, particularly in abductors, has been found in patients with this type of OA (Murray and Sepic, 1968; Jandric, 1998; Arokoski et al., 2002). The functionality of the hip abductor muscles is determinant in the global function of this joint, namely during walking, because of their pelvic stabilizing role (Inman, 1947; Pauwels, 1980; Kapandji, 1996; Kumagai et al., 1997; Fetto et al., 2002). In this way, the importance of the *gluteus medius* (GM) with their ability to generate abductor momentum proportional to its length and lever arm (Pauwels, 1980; Kapandji, 1996) must be considered. So, as with the quadriceps muscle for the knee OA, one might postulate that the main hip abductor muscle (i.e. *gluteus medius*) dysfunction, might affect the OA onset and development (Hurley, 1999; Sims, 1999; Sims et al., 2002).

For instance, in OA patients subjected to total hip replacement (THR), a deficit in the abductor muscles might be related to an intrinsic strength loss of the periarticular muscle, or an indirect result of biomechanical parameter change due to surgical intervention (McGrory et al., 1995; Downing et al., 2001; Asayama et al., 2002), particularly the shortening of the lever arm of the abductor muscles leading to higher tension development to support the body weight during unipodal stance (Johnston et al., 1979; Delp et al., 1996). In fact, despite the general consensus of the benefits for patients subjected to arthroplasty, particularly in pain control and improvement of joint mobility (Laupacis et al., 1993; NIH Consensus Conference, 1995; Altman et al., 2000; Zhang et al., 2005; Hunter and Felson, 2006), this intervention does not always result in muscular strength recovery or normal daily activities fulfilment (Gore et al., 1977; Borja et al., 1985; Skinner, 1993; Nilsdotter et al., 2003). The pending question is whether hip abductor function deficits found in THR patients are more closely related to abductor muscle intrinsic changes, or rather more intimately associated with surgery induced biomechanical parameter alteration, which can be measured through radiographic means.

Macroscopic (Howell et al., 2001) and microscopic (Sirca and Susec-Michieli, 1980) changes of the GM were already described in a significant percentage of THR-subjected patients. Despite the obvious association, no cause-effect relationship has been so far established between hip joint degenerative alterations and periarticular muscle dysfunction; moreover, the relationship between these macro and microscopic findings in the GM of THR submitted patients and post-surgery functional results is far to be comprehended. Nevertheless, based on empirical evidences, post-THR hip muscle strengthening training has been suggested by several authors (Minns et al., 1993; Ueda and Tohkura, 1993; Vaz et al., 1993; Horstmann et al., 1994; Shih et al., 1994; Giurea et al., 1998).

Additionally, the hip biomechanical special characteristics make the functional evaluation difficult, namely the aforementioned role of abductor muscles in pelvic stability during walking; in this case, abductor muscle function of one side is essential for a harmonious load reception and transfer, thus avoiding mechanical shock in both hips; therefore, by studying an abductor muscle like GM, one must hypothesise that its dysfunction may have repercussions both on the ipsilateral and on the contralateral hip.

Theoretically, hip OA disability is mainly explained by the degree of joint degeneration (Bagge et al., 1991; Dekker et al., 1992; Dieppe, 1997), despite hip radiological features and disability not always being well correlated (Lawrence et al., 1966, 1989; Spector and Hochberg, 1994). As an hypothesis, it may be suggested that degenerative changes which modify joint structure, shape, and position with adverse joint biomechanical repercussions are the main responsibles for hip disability, specifically the presence and dimensions of osteophytes, and the intensity and pattern of joint space narrowing; this hypothesis will be supported by the existence of a parallel correlation of these radiographic features with ROM and with hip disability (Dekker et al., 1992; Escalante et al., 1999; Steuljens et al., 2000; Arokoski et al., 2004).

JSW was suggested to be the most important individual characteristic in radiological evaluation of hip OA and on monitoring its progression (Dougados et al., 1996, 1997; Goker et al., 2000; Bierma et al., 2002); the JSW was even considered a better indicator of current clinical situation than universal global scales (Croft et al., 1990), while osteophytes do not seem to be related to the radiological or symptomatic progression of hip OA

(Danielsson, 1966; Dougados et al., 1996). Joint space is also the best relating radiographic measurement to hip pain intensity (Croft et al., 1990; Scott et al., 1992); unlike the hip, however, in knee OA the pain shows a better correlation to osteophytes than to JSW (Spector et al., 1993).

The radiographic cartilage loss pattern in hip OA can be classified in three sub-types (superolateral, concentric and medial), the superolateral being the most frequent (Solomon, 1976; Ledingham et al., 1993); these patterns are associated with femoral head migration in different directions, with subsequent alteration of joint geometry, remaining to be characterised the biomechanical and functional effects of this migration.

Although the JSW narrowing may constitute an important sign of hip OA, there is no consensus concerning the minimum value to radiographically define hip OA since the proposed values vary between 1,5 and 4,0mm (Croft et al., 1994; Spector and Hochberg, 1994). Moreover, the minimum JSW measurement is referred only to a single point of the joint, disregarding location or how much cartilage is left; this difficulty may be overcome using the sum of measurements in three standard points (lateral, superior and axial), located in the weight-bearing region of the joint (Solomon, 1976; Hodge et al., 1986; Jacobsen et al., 2004a; Jacobsen et al., 2004c). This method of evaluating remaining cartilage may be useful in finding joint space narrowing in people subjected to high joint impact, namely certain professionals and athletes to whom counselling is necessary, as well as the timely enforcement of preventive measures for joint sparing. Thus, supposing that the sum of the above mentioned measurements exhibits a better correlation with hip function than the existing one with isolated values, like minimal JSW, the utilization of this methodology may be useful not only for the follow up of hip OA patients, but also in the definition of new radiographic criteria for hip OA diagnosis.

On the other hand, OA Kellgren's Index has been criticised for emphasizing osteophytes, as they are considered part of the normal ageing process (Danielsson, 1966) or because, despite being one of the most characteristic aspects of the OA joint (Altman et al., 1986), their role, meaning and clinical impact are not fully understood (Sandell and Aigner, 2001; Neuman et al., 2003). Osteophytes were proposed to be an endogenous repair attempt of the OA joint, i.e., a physiological response to the instability or mechanical overload (Gelse et al., 2003; Neuman et al., 2003); nevertheless, both humoral and mechanical factors seem to be involved in their origin, stimulating new cartilage and bone development in the sinovial-periosteon joint (Aigner et al., 1995; Mow et al., 1995; Matyas et al., 1997; Felson and Zhang, 1998; Felson et al., 2000; Uchino et al., 2000; Sandell and Aigner, 2001; Gelse et al., 2003; Blom et al., 2004).

Although the joint ROM deficit is normally used as a diagnosis criterion in hip OA (Cyriax, 1957; Lequesne, 1980; Altman et al., 1991; Bierma et al., 1999), there are few studies correlating this parameter with other radiographic characteristics of hip OA, such as JSW or osteophytes dimension and location. According to the hip joint shape, maximal abduction must be limited by bone impact of femoral neck at the upper acetabular edge, although this normally does not occur because of the adductor muscles and iliofemoral and pubofemoral ligaments (Kapandji, 1996); so, it may be argued that the presence of cranial acetabular osteophytes (CAO) would constitute a particular limitation of abduction, since these osteophytes, by prolonging the acetabular edge, might limit this hip movement before the mentioned muscles and ligaments reach their maximal length. On the other hand, if there is a correlation of CAO with abduction, this is probably dependent on the pelvic shape, namely the free-angle (FA), whose apex is located in the centre of the femoral head, and is limited by a line drawn from the lateral extremity of the CAO to the femoral neck point where it hits the CAO during maximum abduction.

Objectives

Considering the above referred, the main objective of this work was to improve the pathophysiology knowledge of hip OA through the characterization and correlation of radiographic, biomechanical, functional, and structural parameters, in order to reach a better clinical diagnosis and treatment management.

The specific objectives were:

1. To study the relationship between pain, ROM, functional deficit and the radiographic hip OA features (narrowing of JSW and osteophytes).

2. To establish the main biomechanical factors of post-THR surgery abductor function.

3. To assess the relationship of abductor muscle structure (*gluteus medius*) with hip OA radiographic findings, age and physical activity.

This work was supported by the following original studies:

1. Amaro A, Sousa L, Sancho L, Meireles J, Calado S, Vitorino R, Amado F, Appell HJ, Duarte JA (2004). Characteristics of the gluteus medius muscle in an asymptomatic patient with radiographic signs of coxarthrosis. *Eur J Orthop Surg Trauma* 14(3): 182-185.

2. Amaro AJ, Amado FM, Appell HJ, Duarte JA (2006). Joint space width and functional impairments in osteoarthritic hips. *Clin Orthop Relat Res* (submitted).

3. Amaro AJ, Amado FM, Vitorino R, Appell HJ, Duarte JA (2006). Cranial acetabular osteophytes limits the maximal amplitude of hip abduction. *Eur J Orthop Surg Trauma* (in press).

4. Amaro AJ, Amado FM, Mendes A, Oliveira J, Malheiro A, Meireles A, Appell HJ, Duarte JA (2006). Radiographic geometric measures of the hip joint and abductor muscle function in patients after total hip replacement. *Eur J Orthop Surg Trauma* (in press).

5. Amaro AJ, Amado FM, Appell HJ, Duarte JA (2006). Does gluteus medius muscle atrophy constitute a primary risk factor to the development of contralateral hip joint osteoarthritis? *Clin Anat* (submitted).

EXPERIMENTAL WORK

Experimental Work

Paper I

CHARACTERISTICS OF THE GLUTEUS MEDIUS MUSCLE IN AN ASYMPTOMATIC PATIENT WITH RADIOGRAPHIC SIGNS OF COXARTHROSIS

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Published on Eur J Orthop Surg Traumatol (2004) 14:182-185

Abstract

This case study describes the micromorphology and some biochemical features of gluteus medius muscle in a 79-year-old woman with radiographic signs of coxarthrosis but with no clinical symptoms, who was initially admitted in the orthopaedic emergency service with a non-displaced subcapital fracture of the femoral neck due to a domestic accident (fall). The X-ray of the hip showed some characteristic features of coxarthrosis, classified grade 2 of the Kellgren criteria. After informed consent, it was decided to carry out the functional evaluation according to the indexes of Lequesne and WOMAC (Western Ontario and McMaster Universities Osteoarthritis Index) and to take a biopsy of the gluteus medius muscle for microscopical examination and myosin heavy chain isoform identification during hip replacement surgery. For the Lequesne Index (score 0–24), the total score was 0, and for the WOMAC (score 0–96), the total score was also 0, both speaking in favour of full joint and muscle function. All the structural features observed in muscle were considered not to have any pathological relevance. The composition of the myosin heavy chains in the gluteus medius muscle was 48% MHC I, 41% MHC IIa, and 11% MHC IIx. The muscle characteristics do not support earlier concepts about muscle weakness as a predisposing factor for osteoarthritis. It is moreover concluded that the diagnosis should rather consider clinical symptoms than radiographic signs of osteoarthritis.

Keywords: Osteoarthritis, Osteoarthrosis, Muscle structure, Muscle function, Myosin heavy chain isoform

Introduction

Osteoarthritis (OA), synonymously named osteoarthrosis, is the most common joint pathology usually related to advanced age and may have a multifactorial and complex aetiology [2, 9, 19]. It is frequently associated with strength deficits among the periarticular muscles [11, 12, 18], which has been attributed to some disuse caused by pain [9, 12]. Longitudinal studies of OA of the knee suggested that quadriceps strength deficits might not only result from pain of the knee but may precede radiographic signs of OA and may represent a risk factor for the development of joint degeneration [23, 24]. Concerning the hip joint, the coxarthrosis (CA) has especially been associated with weakness of the stabilising muscles [4, 16, 21], among which the gluteus medius is of special importance [10].

If the idea holds true that weak periarticular stabilising muscles predispose a joint for OA, signs of atrophy or any pathological alterations at the ultrastructural level should be present in patients with radiographic signs. In this case report, we describe the structural and some biochemical features of gluteus medius muscle in a patient who showed radiographic signs of coxarthrosis, but was clinically asymptomatic.

Case report

A 79-year-old woman with a body weight of 66 kg and body height of 1.60m was admitted to the orthopaedic emergency service of the local hospital with pain and functional impairment of the right hip due to a domestic accident (fall). A supine X-ray of the pelvis showed a non-displaced subcapital fracture of the femoral neck (Fig. 1). It was decided to submit her to surgery for a cemented total hip replacement. The patient had a prior history of osteoporosis (medicated with calcium and vitamin D3), diabetes (medicated with glibenclamide and metformin chlorinate) and ischaemic myocardiopathy (medicated with nimodipine, captopril, and isosorbide mononitrate). The X-ray (Fig. 1) further showed some characteristic features of CA in the right hip, classified grade 2 (score 0–4) of the Kellgren criteria [13]. Evaluating the alterations by the Altman OA Atlas (score 0–3) [1], it exhibited:

Fig. 1 Supine AP X-ray of the right hip joint with a non-displaced subcapital fracture of the femoral neck showing signs of osteoarthritis, a superior acetabular osteophyte, discrete narrowing of the axial articular joint space and acetabular and femoral subchondral sclerosis

- Grade 2 signs—superior acetabular osteophytes
- Grade 1 signs—narrowing of the axial articular joint space, superior femoral osteophytes, acetabular and femoral subchondral sclerosis
- Grade 0 (normal) signs—narrowing of the superior articular joint space, femoral and acetabular subchondral lucencies.

Considering the X-ray signs and the fact that upon anamnestic interrogation the patient had been asymptomatic before this episode, it was decided, after informed consent, to carry out clinical evaluation and to collect a biopsy of the gluteus medius muscle during surgery for microscopical examination and determination of myosin heavy chain (MHC) composition. Since functional tests were not feasible due to the clinical situation, we decided to estimate the functional situation according to the indexes of Lequesne [*14*] and WOMAC (Western Ontario and McMaster Universities Osteoarthritis Index) [*6*].

For the Lequesne Index (score 0–24), which aims at evaluating the degree of symptoms and joint functionality, the total score was 0, since there were neither prior complaints nor functional deficits while walking, climbing stairs, or doing other daily activities. For the WOMAC (score 0–96), which evaluates the degree of pain, stiffness, and functional deficits caused by OA, the total score was also 0, supporting again the results of the previous anamnestic interrogation.

Muscle biopsies were processed using routine histological methods and electrophoretic method [5] for MHC isoform determination. At the light microscopical level (Fig. 2), the muscle fibres appeared normal in diameter and revealed a normal structural pattern. Some fibres, however, showed sarcoplasmic vacuolisation, and the interstitial space contained some adipocytes. At the electron microscopical level (Figs. 3 and 4), some minor ultrastructural alterations were detected, such as focal alterations of the striation pattern. The mitochondrial density appeared to be relatively low, but lipid-droplets were frequently found in muscle fibres. These lipid-droplets should explain the above-mentioned sarcoplasmic vacuolisation, in which case some of them had been washed out due to the histological procedure. A high concentration of glycogen particles was observed in the sarcoplasma. Some inclusions, suggesting lipofuscin-like bodies, were observed, typical for aged muscle. All the structural features observed were considered to be typical for elderly muscle but not to have any pathological relevance.

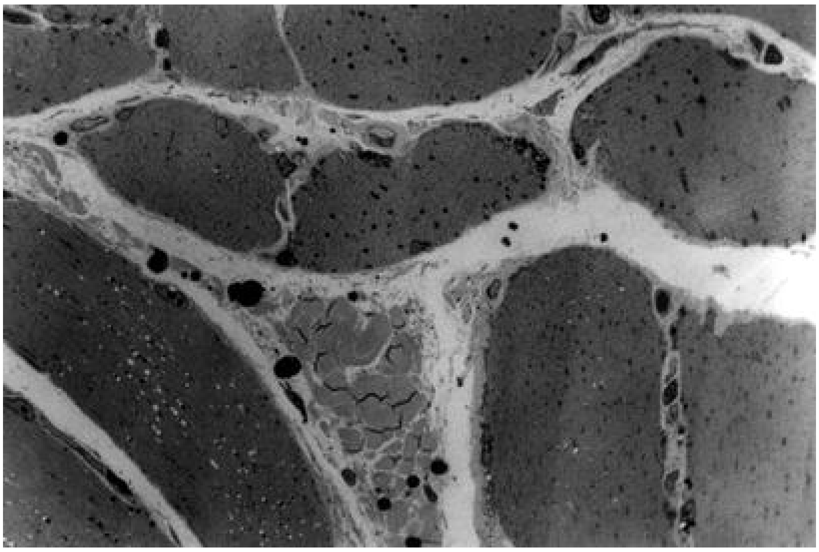

Fig. 2 Light micrograph of the right gluteus medius muscle showing a normal morphology. Note the sarcoplasmic vacuolisation of some fibres and the presence of adipocytes in interstitial space (original magnification ×800)

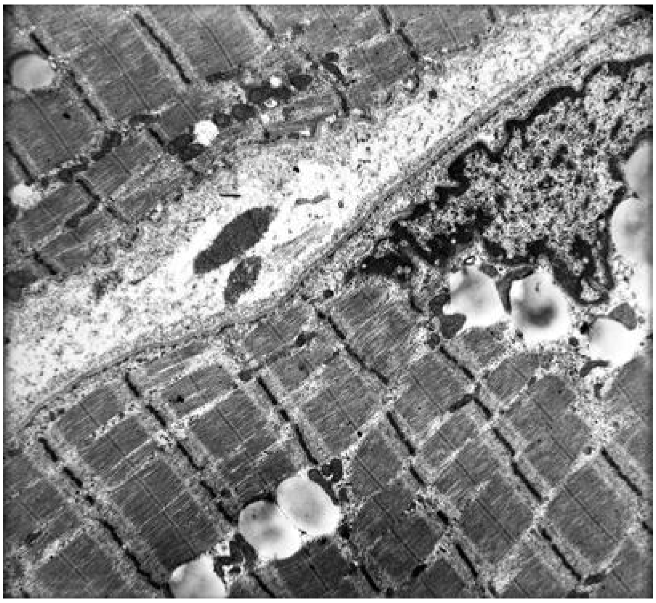

Fig. 3 Electron micrograph of the right gluteus medius muscle shows two muscle fibres containing inter-myofibrillar lipid droplets. In general, both fibres display a normal ultrastructure (original magnification ×8,000)

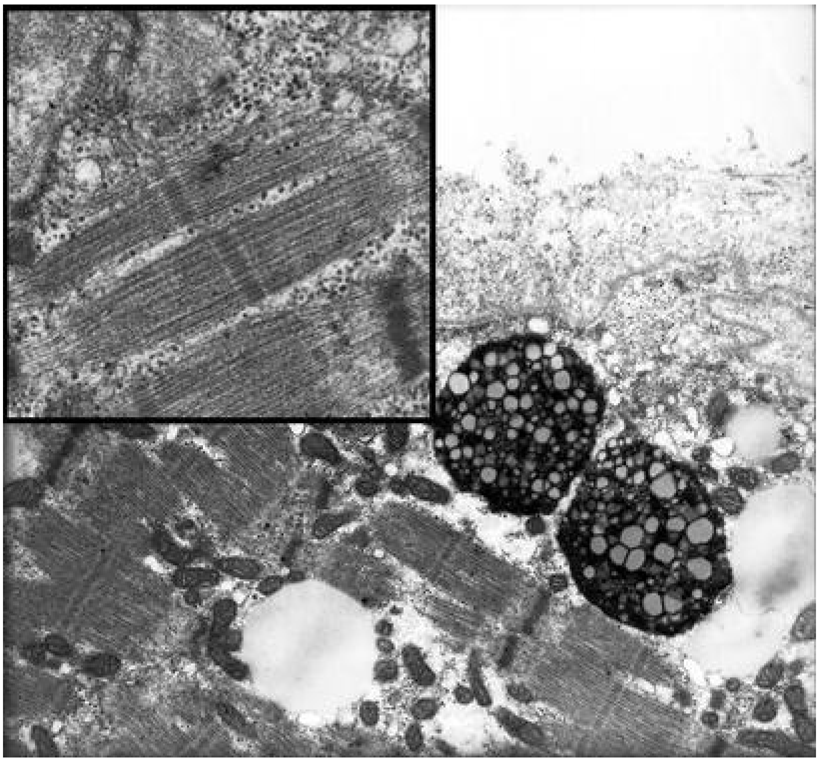

Fig. 4 Electron micrograph of the right gluteus medius muscle showing a muscle fibre with lipid droplets and two sub-sarcolemmal inclusions of lipofuscin-like bodies and small mitochondria between normal myofibrils. The insert shows abundant glycogen within that muscle fibre (original magnification ×12,500 and ×16,000 for the insert)

The composition of the MHC isoforms in the gluteus medius muscle was 48% MHC I, 41% MHC IIa, and 11% MHC IIx, speaking in favour of regular muscle activity, normal muscle strength abilities, and the absence of a typical age-related slowing of this muscle [*15*].

Discussion

In this case study, we did not find morphological nor biochemical signs in the gluteus medius muscle that should justify any attempt to explain the radiological signs of CA being caused by weak or insufficient muscle. In contrary to what could have been expected [*21*, *23*, *24*], the features of muscle structure, including abundant glycogen as energy source, should favour the idea that the gluteus medius muscle of this 79-year-old woman was in good functional condition and in regular use. Although the frequent occurrence of lipid droplets (assumably associated with mitochondrial ageing) and the existence of lipofuscin-like bodies would favour the idea of a senescent muscle, the percentage of the MHC isoform, with an almost equal distribution of MHC I and MHC IIa, rather resembled the situation of a muscle at its best age. The MHC isoform distribution has been described to show a shift towards the slow MHC I in senescent muscles [15].

The obviously good structural condition of the muscle is supported by the outcome of the functional scores. The index of Lequesne and WOMAC showed that the patient was pain free, had no functional deficits, and was able to do all daily activities like stair climbing and others. The notion of a selected type II muscle fibre atrophy in patients with CA [22] cannot be supported by the present case, and it remains to be some kind of "chicken-and-egg" problem as to whether OA provokes muscle alterations or whether muscle alterations provoke OA, or finally, whether a type II fibre atrophy is simply an effect of ageing not directly related to OA. If the theory that muscle weakness initiates OA disturbances [23, 24] holds true, our patient should not have developed radiological signs of CA. It has again to be emphasised that the patient had been completely asymptomatic and would not have been subjected to radiography as a diagnostic tool to detect CA if she had not experienced the accident.

Many factors have to be taken into account for the development of OA; for example, systemic and local biomechanical factors and a complex articular pathophysiology [9]. Among those, osteoporosis was also present in our patient**.** The observed radiographic signs of OA according to the Kellgren criteria [13] and to the Altman OA Atlas [1] might rather be interpreted [17] as the attempt to reinforce the joint in a generally weak bone situation than as typical OA signs in the sense of a degenerative disease [19].

Many joints with radiographic signs of OA do not exhibit pain or other symptoms. In the case of the hip, the degree of narrowing of the joint space seems to be more closely related to pain than other radiographic findings, such as osteophytes or subchondral sclerosis [7, 20]. This aspect gains extra relevance if we establish a hierarchy of radiological findings considering that, in this case, the most significant sign in the X-ray was the superior acetabular osteophytes (grade 2 on the Altman OA Atlas) and not the narrowing of the articular space. Thus, the emphasis on osteophytes given by the Kellgren classification had been brought into question, suggesting that hip osteophytes, namely when no other alterations are present, may be a part of the normal process of ageing [*8*].

This case clearly demonstrates, according to the criteria of the American College of Rheumatology [*3*], that the symptomatic clinical situation should receive more attention than an X-ray when diagnosing osteoarthritis.

Acknowledgment

This work was supported by a grant supplied by Aveiro University.

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Résumé

Cette étude de cas décrit la micromorphologie et quelques caractéristiques biochimiques du muscle gluteus medius (moyen fessier), chez une patiente âgée de 79 ans avec des signes radiographiques de coxarthrose mais sans symptomatologie, qui avait été admise dans le service d'urgence avec une fracture sous-capitale alignée du col du fémur, à la suite d`un accident domestique (chute). La radiographie de la hanche montrait quelques signes de coxarthrose, (degré 2 de Kellgren). Après information et acceptation de la patiente, on a effectué en utilisant les Index de Lequesne et WOMAC, l'évaluation fonctionnelle ainsi qu`une biopsie du muscle gluteus medius pendant l'intervention chirurgicale pour examen microscopique et identification des isoformes da la chaîne lourde de myosine. Pour l'Index de Lequesne (score 0-24), le total a été 0 et pour celui de WOMAC (score 0-96), le score total a aussi été zéro, les deux indices étant favorables à une bonne fonctionnalité musculaire et articulaire. Toutes les caractéristiques structurales observées ont été considérées sans relevance pathologique. La composition des chaînes lourdes de myosine dans le muscle gluteus medius a été de: 48% MHC I, 41% MHC II et 11% MHC IIx. Les caractéristiques du muscle n'appuient pas l'hypothèse que la dysfonction musculaire serait un facteur qui prédisposerait à l'arthrose. On a conclut également que le diagnostic de coxarthrose doit plus prendre en compte les symptômes cliniques plutôt que les signes radiographiques d'arthrose.

Mots Clés: Ostéoarthrite, Ostéoarthrose, Muscle structure, Muscle fonction, Myosine heavy chain isoform

Experimental Work

Paper II

JOINT SPACE WIDTH AND FUNCTIONAL IMPAIRMENTS IN OSTEOARTHRITIC HIPS

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Submitted for publication on Clin Orthop Relat Res (2006)

Abstract

Radiological signs are frequently used to determine the degree of hip osteoarthritis (OA), especially joint space narrowing. The aim of the study was to correlate clinical measures of hip function with radiological signs, introducing a new proposal to measure joint space width (JSW). Fourty patients were included with 71 hips showing osteoarthrosis. Hip pain and function was assessed using the Lequesne Index and passive range of motion, and lateral, superior, and axial as well as minimum JSW was measured in radiographs. The data were analysed using the Pearson correlation coefficient. A significant correlation was found among almost all variables. The highest correlation existed between all functional variables and the sum of lateral, superior, and axial JSW. It is concluded that this new measure representing the weight-bearing area of cartilage may be useful to predict developing hip disabilities.

Keywords: Kellgren Index, Lequesne Index, Hip Biomechanics, Joint Cartilage, Hip function

Introduction

Joint space narrowing, subchondral sclerosis, subchondral cysts and the formation of osteophytes are the most frequent radiological features of osteoarthritis (OA). They are useful to assess the severity of hip OA in a global radiological classification such as the widely used Kellgren & Lawrence`s grading system [10]. Especially the measurement of joint space width (JSW) has been found to well reflect the clinical status and the progression of hip OA [3, 7, 8, 9], since it is the radiographic measurement most closely associated with reported hip pain [5, 15]. Despite its obvious importance, the critical threshold of JSW to define OA is not unequivocal, ranging from 1.5 to 4.0 mm [6, 18].

The radiographic pattern of cartilage loss in hip OA has been classified into three subtypes according to its location, i.e. superolateral, concentric and medial [13, 16], but it remains uncertain whether they represent distinct pathophysiologic entities. Biomechanical studies have shown that the superior pole of the hip is the main area of contact for weight-bearing, which is in agreement with the greater frequency of superolateral narrowing of the JSW in OA hips [16].

Current knowledge suggests that the extent of joint space narrowing and its location are correlated with hip disability, but most studies sought to identify the location of the narrowest JSW. An isolated location with a small JSW does not necessarily allow for the prediction of hip dysfunction related to OA, if other parts of the hip joint are well covered with cartilage. Therefore, not only the smallest JWS might be of interest, but especially its localisation considering the biomechanical situation and the JSW across larger weight-bearing areas of the hip joint.

The aim of the present study was to evaluate the correlation of clinical measures related to hip function and pain with a more global assessment of weight-bearing JSW in patients with OA of different severity.

Materials and methods

Fourty patients (25 males and 15 females, with a mean age of 67.6 +/- 7.7 years, ranging 50-82 years and a BMI of 28.4 +/- 4.0, ranging 20.6-44.6) were referred to the Orthopaedic Department with hip osteoarthritis and gave their informed consent to the objectives and protocol of the study. All of them met the radiographic inclusion criterion of uni- or bilateral hip OA (Kellgren`s score ≥ 2). History of hip surgery or fractures, neurological or muscular disturbances that might interfere with hip joint function, childhood hip disorders or rheumatoid arthritis of any joint constituted the exclusion criteria. From all patients, 71 hip joints match the selection criteria. According to the clinical criteria of the American College of Rheumatology [1] based on the presence of pain in the articular region during the last month and on radiological alterations, 47 (66%) of hip joints met these criteria but 24 (34%) did not.

Clinical examination

The hip pain and function were assessed using the Lequesne Index [14]; the function was also evaluated by the measurement of the passive range of motion (PROM) with a standard goniometer using well-established methods [2]. All tests were done by the same examiner without knowing the respective radiographic findings. Height and weight were recorded and body mass index (BMI [kg/m^2]) was calculated for each individual.

Radiographic evaluation

From each patient, a pelvic radiograph was taken in the standard anteroposterior (AP) view, with the patients in supine position, legs in neutral position, and the X ray tube centered to the pubic symphysis 100 cm above the table. The severity of OA was graded using the Kellgren and Lawrence grading scale and both hips of a given patient were eligible and included if they met the inclusion criterion.

JSW was measured at three locations (lateral, superior and axial); the lateral JSW was measured at the lateral margin of the acetabular subchondral sclerotic line; the superior JSW was measured at the apical transection by a vertical line through the centre of the femoral head; the axial JSW was measured just superior from the fovea (Fig. 1). These quantitative measurements were standardized and performed by the same observer using a 0.1 mm graded ruler. When the minimal joint space (MJS) was not encountered in any of these three locations, a fourth measurement was taken at the point of maximum narrowing. The sum of the lateral, superior and axial JSW was calculated as a marker of the available cartilage to resist to weight-bearing activities.

Statistical analysis

All statistical analyses were performed using the Statistical Package for the Social Sciences (SPSS for Windows v.13.0, Chicago, IL). The respective data for the radiographic and functional parameters were correlated for each hip using the Pearson correlation coefficient with a significance level of 0.05.

Results

The JSW varied considerably among the population studied, as did clinical symptoms and range of motion (Tab. 1). The distribution of Kellgren and Lawrence grade showed that 17 hips (23.9%) had score 2, 31 hips (43.7%) score 3, and score 4 was found in 23 hips (32.4%). With regard to the minimal JSW determined on the radiographs, only 8 hips (11.3%) showed the minimum JSW out (medial) of the weight-bearing surface. Among those remaining 63 (88.7%) hips showing the minimal JSW in the area of weight-bearing, this point was located supralateral in 50 hips (70.4%), it was found in the axial region in 13 hips (18.3%).

A significant correlation was found between the radiographic and functional parameters for almost all variables (Tab. 2). The highest correlation with the Lequesne score was found for the sum of the three (lateral, superior and axial) JSW measurements ($r=-0.67$, $p<0.05$). This superiority of the sum of the three JSW measurements also holds true for the correlations with the other functional parameters (Table 2, printed in bold).

Discussion

Although some studies were not able to show strong correlations between hip pain and OA radiographic signs [11, 12, 18], such correlations appear to become stronger with increasing severity of OA [3, 4, 17]. Seventy-six percent of the patients examined in the present study were considered to have severe OA with a Kellgren index of 3 or more. Not surprisingly, significant correlations existed between radiographic signs of interarticular space narrowing and functional parameters for almost all of the variables studied.

The diagnosis and grading of OA is mainly based on narrowing of the articular space width or on global scales [5, 10]. When determining the minimal JSW, one might be faced with some difficulties to select the exact point where to measure. This may account for the wide variations in defining the threshold of JSW, at which a hip joint is considered to have OA [6, 18]. It appears obvious that a decision based on a single point measurement might not guarantee for great confidence.

This new measure to systematically evaluate the existing articular cartilage across the weight-bearing region of the hip joint is therefore proposed. The sum of the three measurements turned out to show the strongest correlations with the functional parameters and should be considered a valid diagnostic tool in radiographic assessment of hip OA. Since it is strongly correlated with functional impairment and pain that usually forces a patient to seek for the advice of a physician, this measure might also be helpful for the detection of developing yet asymptomatic OA. In this context it also may be meaningful to do repeated measurements over longer periods of time to follow a potential evolution leading to severe symptomatic hip OA or to predict hip disability, especially in middle-aged populations.

Table 1 General characteristics of the sample (*JSW* joint space width)

	n hips	Minimum	Maximum	Mean	Std. Deviation
Kellgren	71	2	4	3.08	0.75
JSW lateral (mm)	71	0	7.2	2.5	1.86
JSW superior (mm)	71	0	5.6	2.4	1.53
JSW axial (mm)	71	0	5.7	3.4	1.39
JSW sum (mm)	71	1.8	15.2	8.3	3.55
minimal JSW (mm)	71	0	3.8	1.5	1.25
Lequesne	69	2	23	11.45	5.11
Lequesne pain	69	0	8	3.81	2.91
Lequesne function	69	2	16	7.64	3.04
Flexion (º)	65	30	135	104.8	20.51
Abduction (º)	65	9	56	31.4	10.57
Adduction (º)	65	9	39	27.4	6.43
External Rotation (º)	65	-10	60	40.0	12.02
Internal Rotation (º)	65	0	42	21.1	10.39

Table 2 Pearson correlations *(PC)* between radiographic and functional hip joint parameters (*JSW* joint space width); (*) Correlation is significant at the 0.05 level

	Lequesne	Lequesne pain	Lequesne function	Flexion	Abduction	Aduction	External Rotation	Internal Rotation
JSW Lateral (L)	-0.52(*)	-0.47(*)	-0.43(*)	0.40(*)	0.50(*)	0.37(*)	0.52(*)	0.33(*)
JSW Superior (S)	-0.57(*)	-0.59(*)	-0.40(*)	0.39(*)	0.50(*)	0.36(*)	0.46(*)	0.25(*)
JSW Axial (A)	-0.39(*)	-0.41(*)	-0.26(*)	0.20	0.30(*)	0.34(*)	0.24	0.25(*)
JSW (L+S+A)	**-0.67(*)**	**-0.66(*)**	**-0.50(*)**	**0.45(*)**	**0.60(*)**	**0.49(*)**	**0.57(*)**	**0.38(*)**
JSW minimal	-0.56(*)	-0.65(*)	-0.32(*)	0.36(*)	0.55(*)	0.42(*)	0.48(*)	0.35(*)

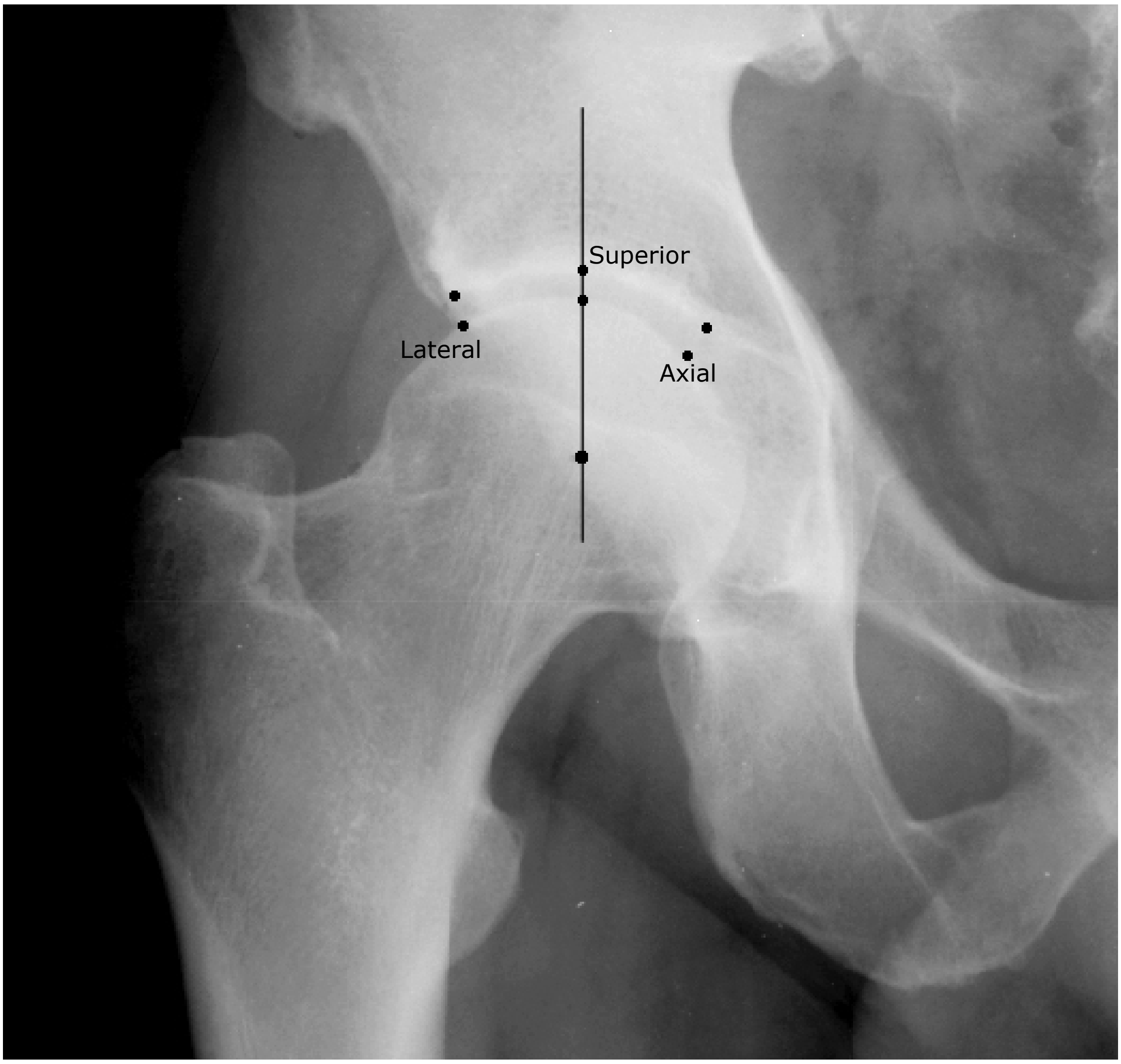

Fig. 1: Radiograph of a hip joint with the points measured for JSW in the weight-bearing area indicated: Lateral, superior, and axial.

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Experimental Work

Paper III

CRANIAL ACETABULAR OSTEOPHYTES LIMIT THE MAXIMAL AMPLITUDE OF HIP ABDUCTION

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Published on Eur J Orthop Surg Traumatol (2006)

Abstract

The aim of the study was to establish a relationship between the existence of cranial acetabular osteophytes (CAO) in hip joints showing varying degrees of degenerative alterations and the range of maximal hip abduction. Seventy-six hip joints from 38 patients (42-82 years old) expecting hip joint replacement because of primary osteoarthritis (OA) were examined; out of those, 50 hip joints showed different levels of OA according to the American College of Rheumatology criteria. The radiological evaluation included the measurement of the length of the CAO and the amplitude of "free-angle" (FA, centered in the femoral head), remaining between the lateral extremity of the CAO and the point where the femoral neck would hit the CAO during abduction. The range of passive motion (ROPM) for abduction was assessed using a goniometer. The correlation between abduction and radiological alterations was calculated with the Pearson coefficient. ROPM in abduction was negatively correlated with the length of CAO ($r=-0.50$; $p<0.01$) and positively correlated with the FA ($r=0.60$; $p<0.01$). The data suggest that the length of CAO plays a key role to limit the ROPM during abduction and that the length of CAO and FA may be useful measures to predict hip function during abduction.

Keywords: Osteoarthritis, Hip joint, Hip movements, Range of motion.

Introduction

Osteoarthritis (OA) of the hip joint is associated with functional impairments and is frequently encountered especially in elderly people [8]. The function of the hip with regard to its range of motion has been correlated with the degree of OA assessed by radiography [4, 5]. Moreover, limitations in hip movements have speculatively been associated with several factors like an increased tightness of the ligamento-capsular complex, muscular contractures, or a remodellation of osteophytes [12], but this context has not systematically been studied.

In spite of the limited value to assess hip joint function per se as a diagnostic criterion of OA [2, 3, 6], it may be at least an indicator for the severity of AO. However, functional measures have never been correlated with the existence or extent of cranial acetabular osteophytes (CAO). Theoretically, maximal hip abduction is structurally limited by the impact of the femoral neck at the upper acetabular edge, although this in reality does not happen because of muscular and ligamentous protective mechanisms [10]. In the case of CAO as a structural extension of the acetabular edge, it may be argued, that this physical limitation reduces the range of abduction. If this hypothesis will be established, a less radical surgical approach, mainly focused to the ablation of the osteophyte, should be considered as a therapeutic tool in hip osteoarthritis.

It was therefore the aim of the present study to establish potential relationships between the existence and extent of CAO and the range of passive motion (ROPM) during hip abduction in hip joints showing varying degrees of osteoarthritis.

Materials and methods

The studied sample consisted of 76 hip joints from 38 patients (25 males, 13 females) with a mean age of 66.2 ± 9.2 years (range 42-82 years). Their major characteristics are individually depicted in table 1. All patients were expecting surgery for total hip replacement, had given their informed consent to the objectives and protocol of the study, and met the inclusion criterion: Diagnosis of uni- or bilateral primary hip OA according to the American College of Rheumatology (ACR) criteria [3]. Exclusion criteria were: Any prior hip surgery or fractures, any neurological or muscular disturbances that might interfere with hip joint function, or sharp hip joint pain during the clinical examination that would inhibit the maximal range of passive motion.

According to the clinical ACR criteria based on the presence of pain in the hip region during the last month and on radiological alterations, 50 (65.8%) hip joints met these criteria, but 26 (34.2%) did not.

<u>Clinical examination:</u> The hip pain was assessed using the pain score of the Lequesne Index [13] with a range from 0 to 8. The ROPM of both hip joints was assessed using a standard goniometer with the patient in supine position. Hip abduction was measured with both hips abducted simultaneously, the goniometer centered over the spina iliaca anterior superior, the stationary arm placed perpendicular to a line between both iliac crests, and the moving arm aligned with the longitudinal axis of the femur in the midline of the anterior thigh. The same physician did all tests without knowing the respective radiographic findings.

<u>Radiographic evaluation:</u> The radiographs (a.p.) of the hip joints were taken in a standardized manner, with the patients in supine position, the legs in neutral position, and the X ray tube centered above the pubical symphysis 100 cm above the table. The severity of OA was graded using the Kellgren and Lawrence grading scale [11].

The length of the CAO extending from the cranial acetabular edge was determined in these radiographs following its inferior border (Fig. 1). Moreover, a line was included from the center of the femoral head to the lateral extremity of the CAO, and the length of this line was measured. This distance was taken as the radius, centered in the femoral head, and was projected downwards until its peripheral end overlaid the lateral femoral neck. This point was regarded to hit the CAO during maximum abduction. The sector between the first line and the second line allowed for the determination of a “free-angle” indicative for the maximum passive abduction until impact of the femoral neck at the CAO (cf. Fig. 2).

Statistical analysis: All statistical analyses were performed using SPSS for Windows v.13.0. The results are expressed as range and median. The respective data for the length of the CAO, free-angle, and ROPM during abduction were correlated for each hip using the Pearson correlation coefficient with a significance level of 0.05.

Results

Individual characteristics of the 38 patients studied concerning general, functional and radiographic hip joint parameters are shown in table 1, that was arranged with regard to the individual subjects. However, for statistical analysis hips were considered individually. In terms of general characteristics the used sample shows a distribution of age ranging from 42 to 82 years old with a male:female ratio of 2:1.The length of the CAO ranged from 0 to 30 mm with a median of 8 mm (mean of 8,9±6.3). The range of the free-angle for abduction was 9 to 61 degrees with a median of 38 degrees (mean of 36.9±10.2) while the ROPM for abduction ranged from 9 to 56 degrees with a median of 32 degrees (mean of 32.8±10.7). The presented parameters are normally distributed.

The Pearson coefficient shows a positive correlation between ROPM in abduction and the free-angle ($r=0.60$, $p<0.01$) and a negative correlation between ROPM and the length of the CAO ($r=-0.50$, $p<0.01$). Taking into account the Kellgreen index as a general tool to radiographically evaluate osteoarthritis, a strong correlation is found with the pain score of Lequesne index ($r= 0.65$, $p<0.01$) and with CAO ($r= 0.51$, $p<0.01$). Moreover, a weaker correlation ($r= 0.38$, $p<0.01$) is also observed between CAO and the pain score of Lequesne index.

The degree of abduction (ROPM) is plotted against the free-angle in Fig. 3, depicting the relationship between the radiologically determined free-angle for abduction and the corresponding functional findings (ROPM). Hip joints, whose structure theoretically allows for a large free-angle, reach a high ROPM during abduction, while structurally altered hip joints with small free-angles show functional impairments.

Discussion

In order to study the hypothesis that cranial acetabular osteophytes may act as main limiting factors for hip abduction, the present work analyzed the correlation between CAO with the range of passive motion during hip abduction in joints showing varying degrees of osteoarthritis. However, it should be understood that similar lengths of CAO could have different individual consequences depending on structural factors such as the shape of pelvis, the design of femoral head and neck as well as the angle between the femoral neck and shaft [10]. Consequently, beyond the length of CAO, also the radiographic free-angle for hip abduction was calculated in order to attenuate the inter-individual variability of the above referred factors [10]. We found a significant negative correlation between hip ROPM and the length of CAO and simultaneously, as expected, an even stronger positive correlation between hip ROPM and the free-angle, which supports the hypothesis that the existence of CAO may constitute an important limiting physical factor for hip abduction.

Although the existence of osteophytes represents one of the most characteristic aspects of osteoarthritic joints [2, 3], their role is not fully understood [17]. Some authors consider them as an endogenous attempt for the repair of osteoarticular lesions in OA joints, being a physiological response to mechanical instability or overload [9, 15, 16]. Independent of their etiology, the correlations observed in the present study suggest that CAO are associated with limitations in hip abduction and this concept is supported by radiographic signs of osteophyte-induced physical limitations to hip abduction (Fig. 2). The biomechanical consequences of a progressive growth of CAO may constitute a good reason to refrain from physical activities or exercises that lead to maximal hip abduction particularly when the movements are abrupt. In fact, since mechanical factors seem to represent an important stimulus for the development of osteochondral appositions in the junction area of the capsule and periost, [1, 7, 8, 9, 14, 17, 18], the CAO growth can probably be reduced when avoiding repetitive traumatic movements. Additionally, it could be argued that in clinical cases of marked CAO-induced reductions of free-angle, with radiographic evidences of the femoral neck impacting to the osteophyte during maximal abduction, the arthroscopic ablation of the osteophyte should be considered as an initial therapeutic and as a secondary preventive measure.

In conclusion, the length of the CAO may represent an important limiting factor for the hip abduction ROM. In this way, CAO length and especially the free-angle can be considered useful markers of abduction ROPM limitations in hips with different degrees of degenerative alterations, like reduced ROPM during abduction may on the other hand be a clinical sign of CAO formation.

Acknowledgments

This study was supported by a grant for health research ("Projectos I&DT em Ciências e Tecnologias da Saúde – 2002") conceded by the University of Aveiro.

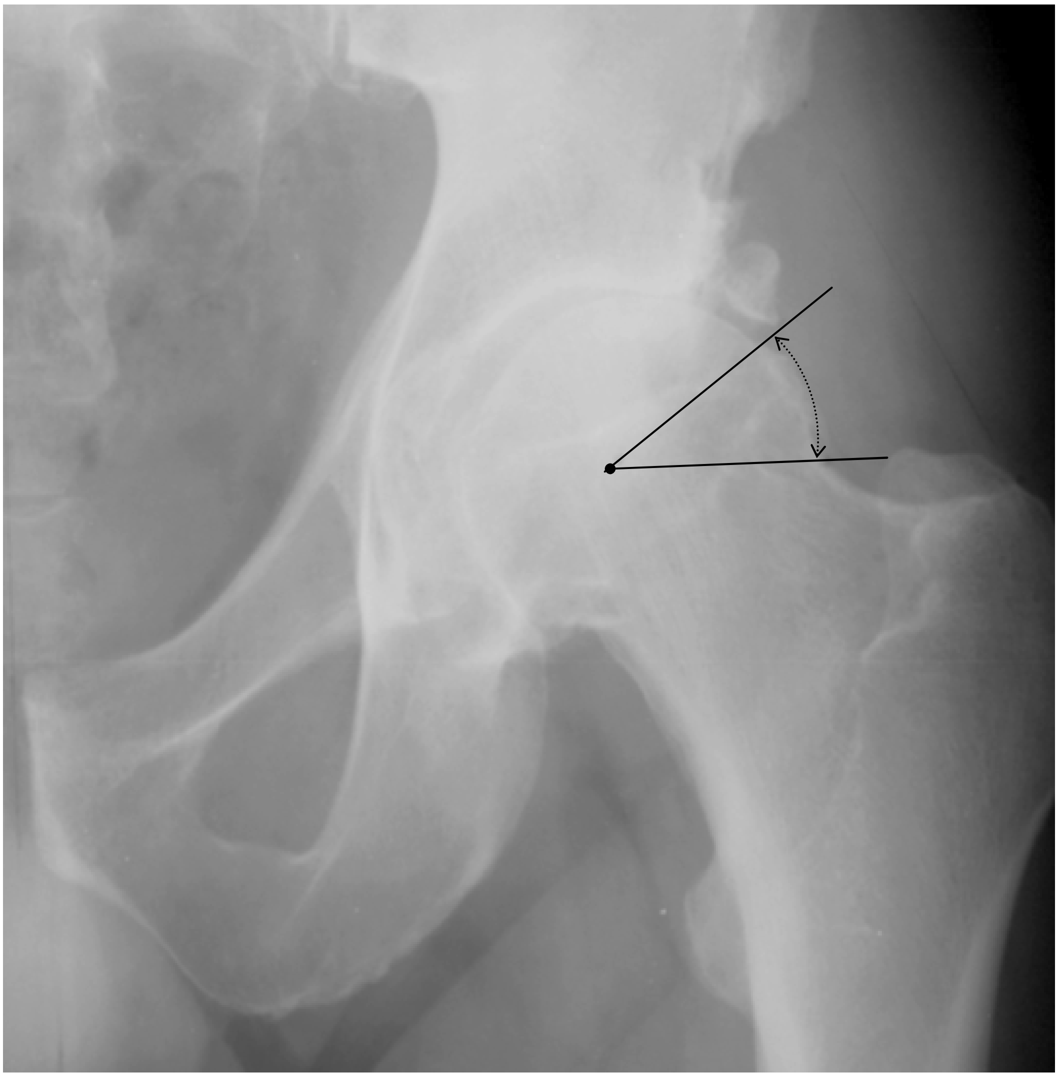

Fig. 1 Radiograph of a hip joint showing CAO; the lines determining the "free-angle" are inserted.

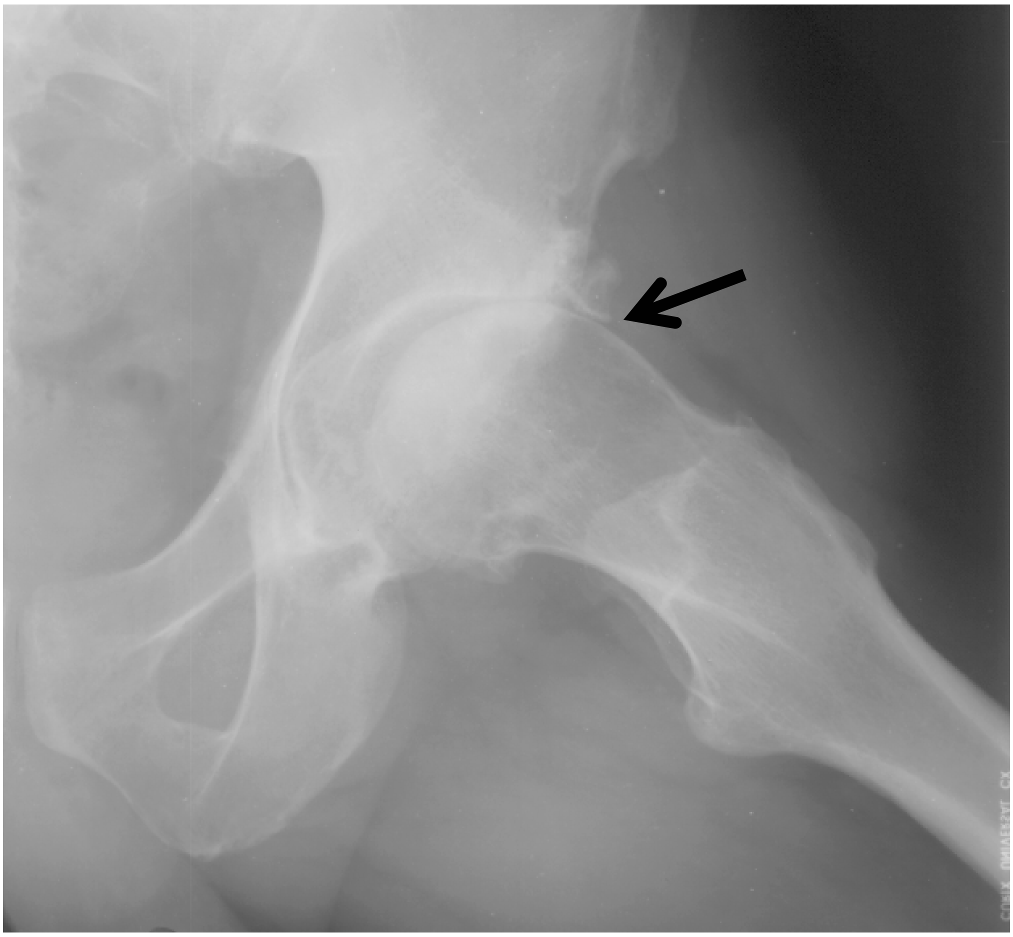

Fig. 2 Hip joint in maximal passive abduction; note the apparent impact of the femur at the ostephyte (arrow).

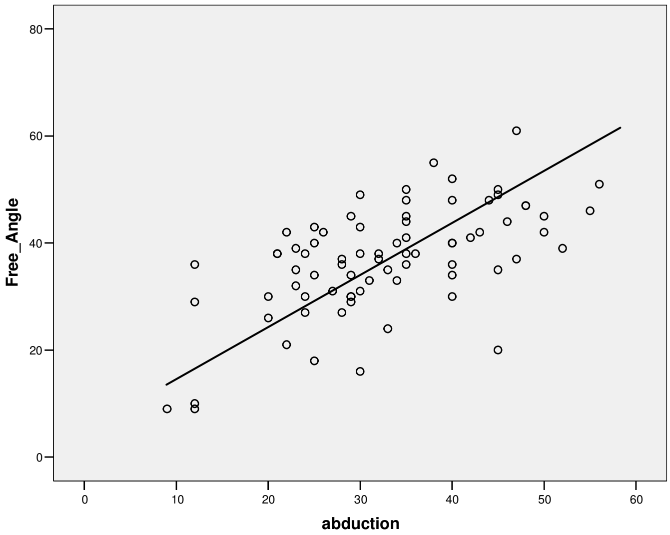

Fig. 3 Plot of abduction (ROPM) in degrees against the free-angle (degrees)

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Table 1 – Individual characteristics of the studied sample concerning general (Age and Gender), functional (Pain: pain score of Lequesne osteoarthritis index; Abd: range of passive motion in abduction) and radiographic hip joint parameters (Kel: Kellgren index; CAO: length of cranial acetabular osteophytes; FA: free-angle).

			Hip joint awaiting surgery					Contralateral hip joint				
Patient	Age	Gender	Kel	Pain	FA	CAO	Abd	Kel	Pain	FA	CAO	Abd
1	78	F	3	4	49	2	30	2	0	50	0	45
2	75	F	3	7	16	20	30	3	3	20	15	45
3	70	M	3	1	36	10	40	2	0	45	0	50
4	62	M	3	3	40	2	40	2	0	46	0	55
5	65	F	4	8	48	8	35	3	3	48	8	40
6	75	M	3	6	38	7	30	2	0	45	8	35
7	82	M	3	6	38	7	24	3	2	34	9	29
8	62	M	4	7	24	7	33	4	7	38	9	32
9	73	M	3	4	37	3	28	1	0	41	0	35
10	68	M	4	3	41	8	42	3	0	47	9	48
11	69	M	4	7	9	30	9	4	7	9	26	12
12	61	M	4	4	31	19	27	3	3	30	16	29
13	65	M	4	5	39	12	23	3	0	35	9	33
14	59	M	4	5	27	12	28	3	0	33	11	31
15	80	M	3	7	40	4	25	2	0	43	0	30
16	74	M	3	1	30	10	24	2	1	30	8	29
17	76	M	4	6	32	8	23	3	5	35	7	23
18	56	M	4	6	38	4	21	2	0	43	3	25
19	59	M	2	3	47	11	48	2	0	51	10	56
20	42	M	4	5	29	7	29	1	0	33	6	34
21	69	M	4	8	38	3	36	3	2	49	12	45
22	76	F	4	8	38	17	21	3	3	42	4	22
23	56	F	2	5	36	5	35	1	5	37	4	47
24	76	F	4	8	10	12	12	3	1	18	6	25
25	50	F	3	5	38	5	35	1	5	55	4	38
26	57	F	3	5	40	5	34	3	4	42	9	43
27	53	M	2	7	40	6	40	2	0	39	7	52
28	59	F	3	8	44	14	35	2	0	48	10	44
29	62	M	4	7	45	2	29	1	0	42	3	50
30	69	M	3	5	34	10	25	2	0	37	7	32
31	65	M	4	4	42	9	26	2	0	44	7	46
32	65	F	3	6	50	12	35	0	2	61	3	47
33	69	M	4	5	26	19	20	4	6	30	16	20
34	73	F	3	3	34	11	40	2	0	30	9	40
35	69	F	3	4	31	8	30	2	1	35	5	45
36	69	M	4	8	29	13	12	4	7	36	22	12
37	76	F	4	6	21	27	22	2	0	27	13	24
38	52	M	3	3	36	15	28	1	0	52	0	40

Résumé

L'objectif de cette étude a été d'établir le rapport entre l'existence des ostéophytes acétabulaires crâniens (OAC) dans les articulations de la hanche avec différents degrés de dégénération articulaire et l'amplitude de l'abduction de l'articulation. Nous avons examiné soixante-seize hanches sur 38 patients (d'âge compris entre 42-82) qui attendaient une chirurgie de substitution articulaire par ostéoarthrose (OA) primaire; 50 articulations d'hanches présentaient des différents degrés de OA basés sur les critères du Collège Américain de Rhumatologie. Les évaluations radiographiques, incluaient la mesure de l'extension de l'OAC et l'amplitude de "l'angle libre" (AL, dont le vertice se trouve situé dans le centre de la tête du fémur), compris entre l'extrémité latérale de l'OAC et le point où le col du fémur se trouve théoriquement en contact avec le OAC pendant l'abduction. L'amplitude articulaire passive (AAP) dans l'abduction a été mesurée avec un goniomètre. La co-relation entre l'abduction et les paramètres radiographiques a été calculée avec le coefficient de Pearson. AAP dans l'abduction a été négativement en corrélation avec l'extension de l'OAC ($r=-0.50$; $p<0.01$) et positivement en corrélation avec l'AL ($r=0.60$; $p<0.01$). Les résultants suggèrent que le OAC a un rôle important dans la limitation de l'amplitude articulaire maximale pendant l'abduction. De cette étude, nous pouvons conclure que l'extension de OAC et l'amplitude de AAP peuvent être des bons indicateurs des limites articulaires, pendant l'abduction.

Mots clés: Ostéoarthrose, Hanche, Mouvements articulaires de l'hanche, Amplitude articulaire

RADIOGRAPHIC GEOMETRIC MEASURES OF THE HIP JOINT AND ABDUCTOR MUSCLE FUNCTION IN PATIENTS AFTER TOTAL HIP REPLACEMENT

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Accepted for publication on Eur J Orthop Surg Traumatol (2006)

Abstract

The aim of this study was to evaluate the correlation between radiographic geometric measurements (abductor lever arm and abductor muscle length) and abductor muscle function in osteoarthritic hip joint patients after surgery. Thirteen patients (11 males and 2 females, aged 55 to 74 years old) were evaluated at least six months after unilateral total hip replacement due to primary coxarthrosis. The length of the abductor muscles and their lever arm were measured on standardized anterioposterior hip radiographs taken in supine position; the product of these two values, namely the Dysfunction Index (DI), was considered an estimate for the hip abductor torque. The abductor muscle function was evaluated through the measurement of the range (degrees) and duration (seconds) of maximal active hip abduction (with patients in lateral decubitus) and through the time sustaining the Trendelenburg test position (single leg stance). Considering the percentage of variation, related to the contralateral hip joint (used as control), a significant positive correlation was found between both, abductor lever length and DI, with the time of maximal hip abduction ($r=0.61$ and $r=0.63$, $p<0.05$). Moreover, a positive trend ($p=0.08$) was found between DI and the time spent in Trendelenburg position ($r=0.54$). The presented data provide evidence that lever arm and DI of hip abductor muscles are correlated with muscular capacity to resist fatigue. These results emphasize the importance of thorough surgical planning before total hip replacement with emphasis to the geometric hip parameters, which seem to determine the clinical outcome.

Keywords: Hip joint surgery; Biomechanical factors; Muscle fatigue; Dysfunctional index; Osteoarthritis; Abductor lever arm

Introduction

The symptomatic hip joint osteoarthritis reaches approximately 3% of the population aged more than 30 years [9] and it is considered one of the major problems of public health in the developed countries due to the functional impairment resulting from pain and limited mobility [21]. The advances in the development of endoprostheses have led hip replacement to become a common practice in orthopaedic departments [10]. In fact, there is a general consensus about the surgical benefits, especially concerning the relief of pain and the improvement in physical function [3, 26]. However, regarding the recovery of muscular strength or the normal performance of daily activities, surgical hip joint replacement does not always lead to favourable results [5, 12, 31].

The functionality of the abductor muscles is crucial for the global function of the hip joint, particularly during walking because of their pelvic stabilizing role [15, 18, 22, 28]. The existence of functional deficits in these muscles can result from an intrinsically reduced muscular strength or may be the indirect result of biomechanical alterations induced by surgical intervention. In fact, from a biomechanical point of view, it should be expected that a shortened lever arm would oblige abductor muscles to develop a higher tension in order to support the body weight during unipodal stance [2, 7, 16, 25]. Moreover, decreases in abductor muscles length could also negatively influence the hip joint functionality [5, 12]. The calculation of a Dysfunction Index (DI) as the product of those two parameters (DI = length of abductor muscles x lever arm) represents an estimate of the hip abductors' torque that should be under the control of the surgeon at the moment of adjusting the prosthesis [5, 30].

The positive correlation between DI and hip joint abductors' functionality was previously suggested [30] using the maximal range of active hip abduction as a marker of hip abductors' functionality. However, if maximal active abduction could be considered an indirect marker of muscle strength, the use of this parameter alone seems to be insufficient to characterize overall muscle performance since it does not give any information about muscle resistance against fatigue. This weakness could be solved by quantifying the period of time spent in maximal abduction as well as by measuring the time of sustaining the Trendelenburg test in such patients.

The aim of this study was to assess whether biomechanical alteration of the joint due to surgery may explain functional impairments. Therefore, radiographically determined geometrical data of totally replaced hip joints were related to the respective abductor muscles functionality. In contrast to a different approach described in the literature [30] for similar goals, the present study used the contralateral hip joint as control and the studied sample was only composed by patients undergoing hip surgery for the first time. Moreover, the abductor muscle fatigability was evaluated by the period spent in Trendelenburg position and by the sustaining period of maximal active abduction.

Materials and methods

This study included thirteen subjects (11 males, 2 females, aged between 56 and 74 years old) that had undergone unilateral hip surgery for total hip arthroplasty (5 cemented and 8 uncemented prosthesis) on Infante D. Pedro Hospital (Aveiro, Portugal) between March and November 2003. Inclusion criteria were the following: i) patients with diagnosis of primary hip osteoarthritis who were ii) submitted to surgery at least six months previously. All patients gave their informed consent about the aims and procedures of the study. The following exclusion criteria were considered: i) earlier hip surgery or hip-related fractures, ii) neurological or muscular disorders with a potentially impaired hip function, iii) body mass index of 40 or more (very obese), or iv) severe radiographic degenerative alterations (graded four in Kellgren Index) of the contralateral hip joint [19]. It should be mentioned that none of the subjects had participated in any rehabilitation program before or after surgery. The examination was done at least six months after surgery (June/July 2004) and included the geometric evaluation of hip a.p. radiographs as well as clinical and functional examinations involving amplitude and duration of maximum active abduction in lateral decubitus, and the Trendelenburg test with regard to the period of maintaining correct pelvic posture.

Geometric radiographic evaluation

Anteroposterior supine radiographs of the hips were done in a standardized fashion with the hips in neutral position, and the X-ray tube centered above the pubic symphysis at a distance of 100cm from the table. All measurements were done by the same individual using the same criteria for the reference points. In the same radiograph of the pelvis, including both hip joints, the following parameters (depicted in Fig. 1) of the operated and non-operated hip were measured: i) the length of the abductor muscles, estimated by the distance between the anterior superior iliac spine and the upper lateral margin of the greater trochanter; ii) the lever arm of the abductor muscles, evaluated by the perpendicular distance between the virtually projected abductor muscle line (used for measurement of abductor length) and the center of the femoral or of the prosthesis head, respectively, and iii) the lever arm of the body weight, estimated by the perpendicular distance between the midline of the pubic symphysis and the center of the femoral or of the prosthesis head, respectively. DI was obtained by the product of parameter i) and ii).

Clinical evaluation of abductor function

The function of the abductor muscles was assessed with the following tests: i) maximum active abduction range of the leg (degrees) with the patient in lateral decubitus maintaining the knee joint extended and avoiding any pelvic co-movements, ii) time spent in maximum active abduction with oscillatory movements less than five degrees; iii) time spent in Trendelenburg position.

All these functional tests were performed by the same physician who was blinded for the results of geometric radiographic parameters.

Statistical analysis

All results were presented as means and standard deviations of the absolute values and of the percentages of variation of the operated hip related to the non-operated (contralateral) hip. After analyzing the normal distribution of the sample with the Kolmogorov-Smirnoff test, the absolute values of operated and non-operated hip joints were compared using the paired sample t-test. Correlations between the percentage of variation of the geometric radiographic measures and functional data of the abductor muscles were obtained using stepwise multiple regression analysis (Andade). The significance index was set as $\alpha = 0.05$.

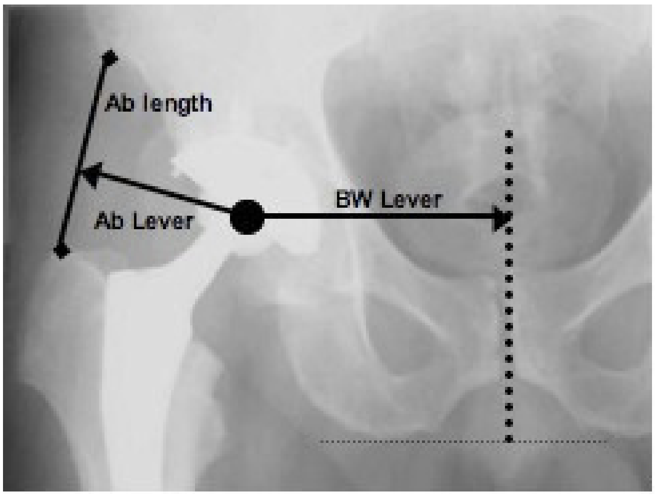

Fig. 1 Postoperative hip joint X Ray of a patient illustrating the studied geometric parameters concerning abductor muscles (Ab) and body weight (BW)

Results

Table 1 summarizes the general characteristics of the patients. Apart from differences in sex, age, height and weight, the implanted prosthesis (cemented and uncemented) also differed with respect to the length of the neck, ranging from short to extra long.

The measurements performed on radiographs showed a large variation in the length of the abductor muscles between the operated and non-operated hip (Table 2). Compared to the non-operated hip, the percentage of variation of abductor muscle length in the operated hips ranged from -4.7% (shorter) to 41.2% (longer). Their mean length across the group was 7.85±0.87 cm in the operated leg and 7.09±1.07 cm in the non-operated hip (p=0.002).

The percentage of variation of the abductors lever arm also differed considerably between the non-operated and operated hips (-31.3% to 10.3%). The lever arm was longer (resulting in favorable biomechanical alterations) in only three cases, while it was shorter in the other ten cases after hip replacement. The mean length of the lever arm was 6.12±0.88 cm in the operated hips compared to 6.55±0.55 cm (p=0.07) in the non-operated contralateral controls. It was noticed that the lever arm did not become longer in any of the cases that had received prosthesis with a short neck (cf. tables 1 and 2, Fig. 2).

Table 1 General characteristics of the sample (*Cem* cemented prosthesis, *Ncem* Non-cemented prosthesis, *S* short neck, *M* medium neck, *L* long neck, *XL* extra long neck, *Post* posterior approach, *Lat* lateral approach)

Patient nº.	Weight [Kg]	Height [Cm]	Age [Years]	Prosthesis Type	Neck Length	Surgical Approach
1	64	159	70	Cem	M	Post
2	90	165	62	Ncem	L	Post
3	51	154	65	Ncem	M	Post
4	92	168	62	Ncem	S	Lat
5	59	156	73	Cem	S	Lat
6	76	172	68	Ncem	S	Lat
7	69	165	65	Cem	XL	Post
8	79	180	74	Ncem	M	Post
9	67	163	56	Ncem	M	Post
10	80	165	59	Ncem	S	Post
11	80	162	69	Cem	M	Post
12	88	162	57	Ncem	S	Post
13	61	155	64	Cem	S	Lat

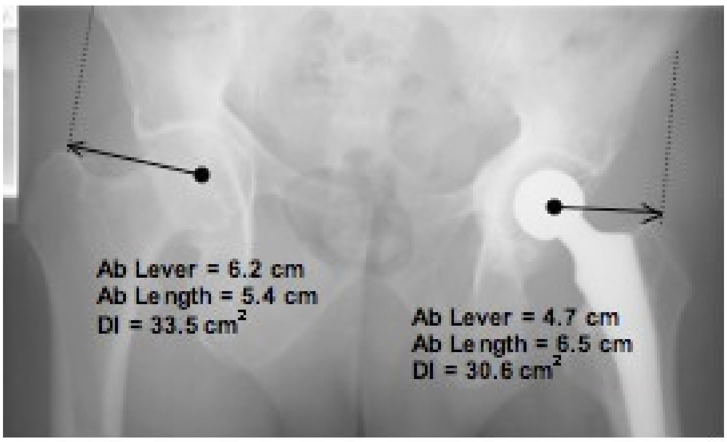

Fig. 2 Example of a postoperative pelvic radiograph (from patient nº 5) presenting notorious differences in abductor muscles (Ab) geometric parameters and in the resulting Dysfunction Index (DI) between operated and non-operated hip joints

The percentage of variation of the body weight lever arm hardly differed in the operated when compared to the non-operated hip (-8.2% to 5.1%). A slightly reduced length, assumably improving the biomechanical conditions for the abductors, was found in six cases. The mean length of the body weight lever arm was 9.72±0.90 cm in the operated hips vs. 9.88±0.84 cm (p=0.30) in the non-operated hips.

The percentage of variation of the DI ranged from -30.3% to 29.8%, with negative values (speaking in favor of impaired biomechanical conditions) in five cases. The mean DI levels were 48.4±10.45 cm^2 in the operated hip and 46.63±9.18 cm^2 in the contralateral hip (p=0.45).

Table 2 Individual percentage of variation (%Δ) of radiographic hip geometric parameters (*Ab* abductor muscle, *DI* dysfunction index, *BW* body weight).

Patient nº	%Δ Ab Length	%Δ Ab Lever	%Δ DI	%Δ BW Lever
1	21.9	-1.6	20.0	-7.8
2	11.5	10.3	23.0	4.6
3	8.6	7.8	17.1	-7.9
4	41.2	-8.1	29.8	0
5	20.4	-24.2	-8.8	-6.4
6	10.8	-2.8	7.7	0
7	16.5	-6.0	9.5	3.1
8	-4.7	-2.6	-7.2	-1.9
9	0	-16.2	-16.2	-8.2
10	0	-8.5	-4.1	4.0
11	18.7	6.3	26.1	3.1
12	7.9	-6.3	1.3	-8.2
13	1.4	-31.3	-30.3	5,1

When compared to the non-operated side, the percentage of variation of the maximal hip abduction angle in the operated hip varied from -59.5% to 15.9%, being positive in only one case (table 3). The percentage of variation of the time spent in maximal active abduction ranged from -61.2% to 46.9%, with unchanged or enhanced results in four cases and decreased outcomes in seven patients. Compared to the non-operated hip joint and regarding the time spent in Trendelenburg position, five patients revealed lower periods in the operated hip while six subjects showed unchanged or even superior results (Table 3).

Table 3 Individual percentage of variation (%Δ) of hip abductor functionality (*MAA* maximum active abduction, *tMAA* time of maintained maximum active abduction, *tTP* time spent in Trendelenburg position, *NA* not available. The cases where the Dysfunction Index was smaller in the operated hip than in the non-operated hip are shown in bold).

Patient nº	% Δ MAA	% Δ tMAA	% Δ tTP
1	-6.0	-12.1	0
2	-19.4	0	0
3	-37.5	-8.9	-58.6
4	NA	NA	NA
5	**-59.5**	**-49.4**	**-76.4**
6	15.9	46.9	-20.1
7	-8.8	-49.8	170.9
8	**-8.1**	**-50.8**	**-80.2**
9	**NA**	**NA**	**NA**
10	**-1.8**	**0.7**	**67.9**
11	0	25.9	415.5
12	-22.5	-20.1	0
13	**-38.6**	**-61.2**	**-100**

The correlation data between geometric and functional parameters is presented in Table 4. Considering the percentage of variation, relatively to the contralateral hip joint, a significant positive correlation was found between both, abductor lever length and DI, and the time of maximal hip abduction ($r=0.61$ and $r=0.63$, $p<0.05$). A positive trend ($p=0.08$) between DI and the time spent in Trendelenburg position ($r=0.54$) was found. The correlation between the range of maximal active abduction and the geometric parameters was not significant.

Table 4 Pearson correlations between percentages of variation (%Δ) of geometric and functional hip joint parameters (*Ab* abductor muscle, *DI* dysfunction index, *BW* body weight, *MAA* maximal active abduction, *tMAA* time spent in maximal active abduction, *tTP* time spent in Trendelenburg position. The significant correlations are depicted in bold).

	%Δ MAA		%Δ tMAA		%Δ tTP	
	r	p	r	p	r	p
%Δ Ab Length	-0.08	0.82	0.22	0.52	0.40	0.22
%Δ Ab Lever	0.50	0.12	**0.61**	**0.04**	0.39	0.23
%Δ DI	0.41	0.21	**0.63**	**0.03**	0.54	0.08
%Δ BW Lever	0.34	0.32	0.08	0.81	0.37	0.27

Discussion

Regarding methodological aspects, it could be argued that the objectives of our study could be better achieved comparing preoperative with postoperative data. However, it is important to be aware that marked radiographic alterations with severe repercussions in geometric parameters were preoperatively found in the operated hip joint in the majority of subjects, attaining grade 4 of Kellgren index [19] in six patients. Moreover, it could be expected that functional evaluations would be also biased by preoperative pain, which then would have positively influenced the postoperative functional results when compared to the pre-surgery situation. To avoid these limitations we had opted for a transversal design after surgery, comparing the operated with the contralateral hip joint. In addition, the intraindividual comparison of radiographic and functional data between the operated and contralateral hip joint allowed attenuating the influence of systemic conditioning factors such as age, sex, physical training and psychological state.

Using this methodological design, all the changed parameters should individually be explained by local factors. It is widely accepted that among these local factors, the abductor muscles play an important role in the pelvic stabilization during walk. In fact, although the functional importance of the iliotibial tract harnessed by the tensor of fascia lata and of gluteus maximus muscles has received increasing biomechanical attention in the stabilization of the hip during unipodal stance or during walking [11], the length of gluteus medius and minimus and their lever arm still seems to be decisive for hip stabilization. Considering that the gluteus minimus and medius performance depends on the intrinsic capacity to generate force and also on hip joint geometry [28], we applied the maximal active abduction (marker of strength), and the time spent in maximal active abduction and in Trendelenburg position (markers of muscle fatigability) as parameters to evaluate those factors.

Hip joint functionality, particularly the abductor function, is usually evaluated in a quantitative way by the measurement of maximal active abduction [6, 23, 30] and qualitatively by the overall outcome of the Trendelenburg test ("positive" or "negative") [8, 13, 27]. Although the maximal active abduction depends on the muscle capacity to generate force, this parameter does not give any information about muscle fatigue, which seems to be an important property to meet the mechanical challenges of daily life since abduction muscles are responsible for pelvic stabilization during unipodal support, especially during walking. Considering these continuous mechanical challenges put upon abductor muscles, it seems more important to highlight the muscle ability to resist to fatigue than muscle strength. In this way, the periods spent in the Trendelenburg position and in maximal active abduction observed in our study were regarded as indicators of muscular endurance when the abductors are in "neutral" and in shortened position.

Radiographic and functional data obtained after total hip replacement showed a large interindividual variability and, in about half of the cases, a muscular dysfunction similar to the non-operated hip joint. After more than six months post surgery, a superior or at least identical muscular abduction functionality should be expected compared to the contralateral hip joint since 12 of the 13 patients had a degree 2 or 3 of Kellgren index [19] in the non-operated hip and five of them presented a clinical symptomatic OA according to the American College of Rheumatology criteria [1]. In our study, the existence of patients with different recovery periods after surgery (between 6 and 14 months) should not have influenced the results, because it had been shown that hip endoprosthesis patients recover well during the first six months and do not gain significant additional hip function afterwards [24, 31].

In our sample, the maximal active abduction in the operated hip showed inferior values than the contralateral hip joint in 9 subjects; however, from those cases only 7 patients presented lower values in the time spent in maximal active abduction and only 4 subjects showed a decrease of time spent in Trendelenburg position. Since results from these functional parameters do not match well, it could be concluded that the typical functional test employed in an isolated way is not sufficient to clinically assess the overall hip function. Consequently, during clinical practice, the use of different tests measuring different functional parameters (strength and fatigability) is mandatory for a precise medical judgment.

It could be observed that only 3 patients (Tables 2 and 3) presented unequivocal results between radiological (DI and lever arm) and all the three functional parameters. Two of these 3 cases (subject nº 5 and subject nº 13) have in common a short femoral neck and, simultaneously, the shortest lever arms of the abductor muscles, when compared to the contralateral hip. It should be noted, however, that these two patients have also been operated with the same lateral approach technique [14]. Some authors have assumed that this approach has a higher risk for a reduced post surgery abductor function due to muscular lesions or to a possible damage of the upper gluteal nerve [4, 20, 29]. Nevertheless, other authors did not report significant functional differences after lateral vs. posterior approaches [8, 17]. In our study, 9 patients were operated using a posterior approach and 4 patients using a lateral one. Taking into account, for instance, the time spent in maximal active abduction, we observed unfavorable results in 7 cases; from those, 5 patients were operated with a posterior approach and the other 2 patients with a lateral one. Considering this data and the significant correlation found between radiological parameters with the time spent in maximal active abduction, it appears justified to suggest that the surgical approach is a minor factor to explain hip joint dysfunction after surgery. In fact, taking into consideration the relative values of the studied parameters, a significant correlation could be observed between the lever arm of abductor muscles and DI with the time spent in maximal active abduction. In the same sense, despite not having been significant (p=0.08), some correlation was also observed between DI and the time spent in Trendelenburg test.

In conclusion, this study showed that the evaluation of hip joint functionality is complex and demands the analysis of several muscle attributes such as the capacity to generate force and the ability to resist fatigue. The presence of a lower radiographic Dysfunction Index and, especially, a reduced lever arm of abductor muscles in the replaced hip is strongly correlated with a poorer abductor function. The present results emphasize the importance of a thorough surgical planning of total hip replacement involving the geometric radiographic conditions, namely lever arms and abductor measurements, which seem to determine better clinical results.

Acknowledgments

This study was supported by a grant for health research ("Projectos I&DT em Ciências e Tecnologias da Saúde – 2002") conceded by the University of Aveiro

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Résumé

Le but de cette étude est d'évaluer la corrélation entre les mesures géométriques radiographiques (bras de levier abducteur et longueur de muscle abducteur) et la fonction abductrice du muscle dans les patients osteoarthritic de joint de hanche après une chirurgie. Treize patients (11 mâles et 2 femelles, âgés de 55 à 74 ans) ont été évalués au moins pendant six mois après le remplacement total unilatéral de la hanche dû au coxarthrosis primaire. La longueur des muscles abducteurs et leur bras de levier ont été mesurés sur les radiographies antéropostérieures normalisées de la hanche prises en position de supination; le produit de ces deux valeurs, à savoir l'index de dysfonctionnement (DI), a été considéré une évaluation pour le couple abducteur de la hanche. La fonction abductrice du muscle a été évaluée par la mesure de la gamme (degrés) et de la durée (secondes) de l'abduction active maximale de la hanche (avec des patients en décubitus latéral) et par le temps soutenant la position du test de Trendelenburg (position simple de jambe). Vu le pourcentage de la variation, lié au joint contralatéral de hanche (utilisé comme commande), une corrélation positive significative a été trouvée entre tous les deux, longueur abductrice de levier et DI, avec une période de temp d'abduction maximale de la hanche ($r=0.61$ et $r=0.63$, $p<0.05$). D'ailleurs, une tendance positive ($p=0.08$) a été trouvée entre les DI et le moment passé en position de Trendelenburg ($r=0.54$). Les données présentées fournissent l'évidence que le bras de levier et les DI des muscles abducteurs de la hanche sont en corrélation avec la capacité musculaire de résister à la fatigue. Ces résultats soulignent l'importance de la planification chirurgicale complète avant le remplacement total de la hanche en soulignant les paramètres géométriques radiographiques de la hanche, qui semblent déterminer les résultats cliniques.

Mots clés: Chirurgie de la hanche, Facteurs biomécaniques, Fatigue musculaire, Index de dysfunction, Ostéoarthrite

Experimental Work

Paper V

DOES GLUTEUS MEDIUS MUSCLE ATROPHY CONSTITUTE A PRIMARY RISK FACTOR TO THE DEVELOPMENT OF CONTRALATERAL HIP JOINT OSTEOARTHRITIS?

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Submitted for publication on Clin Anat (2006)

Abstract

Trying to understand the role of gluteus medius muscle (GM) in hip joint osteoarthritis (OA), the objective of this study was to analyze in 41 patients (16 females, 25 males) with different grades of OA at both hips, the hypothetical correlation between histological morphometric data of GM samples obtained during hip replacement surgery with the OA radiographic scores of ipsilateral and contralateral hips. GM samples were submitted to routine histological procedures to calculate muscle fibers area (MFA), capillaries per fiber, % of interstitial space (%IS), and % of interstitial area occupied by adipocytes (%IA). The hip OA was graded using the Kellgren Index (KI) and measuring the joint space width (JSW) in different articular locations. Results evidenced a wide MFA variation with an average of 1448±587mm2. The mean %IS and %IA was 35.6±8.3% and 3.4±2.8%, respectively. KI average in operated and non-operated hip were 3.1±0.8 and 2.2±0.9, respectively ($p<0.05$); the minimal JSW was also more pronounced in the operated hip comparing to non-operated one (1.6±1.5 vs 2.9±1.2; $p<0.05$). Significant correlations were found between MFA and the level of radiographic signals of OA in both ipsilateral ($r=0.38$, $p<0.05$) and contralateral joint ($r=0.50$, $p<0.05$). Although reduced MFA can be explained by disuse induced by ipsilateral OA pain ($r=0.32$, $p<0.05$), the existence of a higher correlation with the contralateral hip radiographic parameters suggests that GM atrophy may constitute a primary risk factor to the contralateral OA development.

Keywords**: Muscle histology, Muscle fiber area, Morphometry, Kellgren index, Joint space width**

Introduction

The maintenance of joint function depends on an intact structure of its components, especially articular cartilage, but also on the functional and structural integrity of the muscles acting on and supporting a joint (Hurley, 1999, 2002; Felson et al., 2000; Hunter and Felson, 2006). Weak muscles are assumed to reduce joint stability and mechanical shock absorption (Slemenda et al., 1997, 1998; Hurley, 1999), and may predispose a joint to develop osteoarthritis (OA). However, in a classical point of view, the strength deficits or the atrophic evidences of these muscles are usually seen as a consequence of OA, i.e., an outcome of disuse induced by articular pain (O´Reilly et al., 1997, 1998; Hurley, 1999; Felson et al., 2000). Which process precedes the other one, has not yet been clarified. The interdependence of OA and alterations of periarticular muscles have especially been studied for the knee joint and the quadriceps muscle (Sun et al., 1997; Hurley, 1999; Arokoski et al., 2002). It has been argued that a weak quadriceps muscle cannot produce the enough strength to stabilize the knee and to prevent overload during the amortization of the mechanical impact during gait (Slemenda et al., 1997, 1998; Hurley, 1999).

The osteoarthritic hip joint has been less studied in this respect, but a reduced force of the gluteus medius muscle (GM) has already been associated with hip OA (Murray and Sepic, 1968; Sims, 1999; Arokoski et al., 2002; Sims et al., 2002). However, the biomechanical situation around the hip appears more complicated than that around the knee. In fact, while the interaction of muscle and knee joint can be looked at unilaterally, the hip joints and the abductor muscles interact bilaterally during gait (Pauwels, 1980; Kapandji, 1996; Watelain et al. 2001; Fetto et al., 2002). When body weight gets supported by the hip joint of one side during gait, the ipsilateral abductors have to stabilize pelvic equilibrium in the frontal plane and ensure a smooth load transfer by their eccentric contraction in order to avoid excessive shock impact on the contralateral hip joint (Inman, 1947; Winter, 1991; Kapandji, 1996; Kumagai et al., 1997). If functional impairments of muscle contribute to the development of OA, the occurrence of hip OA may be initiated by structural and functional alterations of contralateral muscles, especially the GM as the principal abductor of the hip.

It therefore appears challenging to study the morphology of gluteus medius muscle and to correlate it with the level of radiographic signs of OA not only with the ipsilateral hip joint but also with the contralateral hip joint. According to the classical concept for muscle responses in OA, an atrophic effect can be expected in the ipsilateral gluteus medius muscle of an OA hip joint induced by disuse. However, considering the hypothesis that muscle dysfunction may constitute a predisposing factor to the development of OA and taking into account the important function of abductor muscles to ensure a smooth load transfer to the contralateral hip joint during daily life activities, it could be expected that the degree of OA in a hip joint may have a reasonable correlation with the morphometric characteristics of the contralateral gluteus medius muscle. It was, therefore, the aim of the study to analyze biopsy samples of GM obtained during surgery for unilateral hip replacement and to take radiographs and clinical scores of both hip joints for correlation analysis.

Materials and methods

The sample was composed of 41 patients (16 females and 25 males) with different degrees of OA at both hips, which were submitted to unilateral hip surgery at the local orthopaedic hospital. History of previous hip surgery or the presence of other acute or chronic conditions that might interfere with hip function and muscle structure, namely neurological or musculo-skeletal disorders, were considered exclusion criteria. This work was approved by the local Ethical Board and all patients gave their informed consent to participate in the study, including the muscle biopsy collected during hip surgery. Patients were questioned about their daily present and past physical activity (before the onset of clinical symptoms), using an adapted version of the "Health Insurance Plan of New York Questionnaire" (Shapiro et al., 1965). The questionnaire evaluates the physical activity at professional and leisure level, leading to a score ranging from 1 to 41. For both operated and non-operated hips, the articular pain was assessed in the day before surgery using the Lequesne Index (score 0 to 24), according to the methodology described elsewhere (Lequesne et al., 1987).

Histological Evaluation

During surgery, two samples of the ipsilateral gluteus medius muscle were collected, one from the medium part and the other from the posterior region of the muscle, each one with a size of approximately 10x10x5mm. Muscle samples were immediately processed using routine histological procedures for light and transmission electron microscopy analysis. Briefly, after fixation with glutaraldehyde and post-fixation with osmiumtetroxide, the samples were dehydrated in graded alcohol, and embedded in Epon. Semithin sections (2mm) were stained with methylene blue for light microscopy, and ultrathin sections (200nm) were examined in the transmission electron microscope (Zeiss EM 10A) after contrasting with uranyl acetate and lead citrate. The morphometric parameters were evaluated in light micrographs of muscular cross-sections, with an original magnification of 640x; the photos were scanned and digitized for posterior analysis with the NIH Image J software (v. 1.36 for Windows, ftp://rsbweb.nih.gov/pub/image-j/). The analyzed parameters in each micrograph were the muscle fiber area, the number of capillaries contacting to each fiber, the percentage of interstitial space, estimated as the difference between the total area of micrograph and the total fiber area per section, and the percentage of interstitial space area occupied by adipocytes. More than 100 muscle fiber profiles were evaluated in each muscle sample from four randomly chosen blocks of each specimen, according to the methodology described by Soares and Duarte (1991), and averagely 175 fibers were analyzed per sample. Gluteus medius muscle ultrastructure was qualitatively evaluated in the electron microscope.

Radiographic evaluation

Pre-operatory radiographs of the hip joints were taken in a standardized mode, with the patients in supine position, the legs in neutral position, and the X-ray tube centered above the pubical symphysis 100cm above the table. The OA of each hip was graded using the Kellgren Index (Kellgren and

Lawrence, 1957) and the joint space width (JSW) was measured at three locations (lateral, superior and axial), as depicted in Figure 1, according to Jacobsen et al. (2004). Briefly, the lateral JSW was measured at the lateral margin of the acetabular subchondral sclerotic line; the superior JSW was measured at the apical transection by a vertical line through the centre of the femoral head; the axial JSW was measured just above the fovea. These quantitative measurements were standardized and performed by the same observer using a 0.1 mm graded ruler, and the sum of the three measurements was taken to assess total JSW as an estimate of functional cartilage thickness. When the minimal joint space width was not found in any of these three locations, a fourth measurement was taken at the point of maximum narrowing.

Statistical analysis

All statistical analyses were performed using the Statistical Package for the Social Sciences (SPSS for Windows v.13.0, Chicago, IL). The normal distribution of the dependent variables was verified with the Kolmogorov-Smirnoff test. Data are expressed as the mean ± standard deviation. Significant differences of radiographic variables between both hips were tested with paired t-Test. The respective data for the dependent (morphometric and radiographic parameters) and independent (age, daily and past physical activity, and Lequesne Index) variables were correlated to each hip joint using the Pearson correlation coefficient. The significance level was set for a a=0.05.

Results

The patients were on average 68.4±9.4 years old, ranging from 42 to 83 years, with daily and past physical activity scores of 8.1±6.0 and 21.9±5.3, respectively. The past physical activity is referred to the epoch of onset of clinical symptoms, which in average had occurred 3.2±1.1 years before. As expected, radiographic signs of OA, documented by the Kellgren index and

JSW measured at different locations, appeared significantly more pronounced at the operated hip than at the non-operated hip (Tab. 1).

Considering the morphometric results of gluteus medius muscle (Tab. 2), the mean cross-sectional fiber area was 1448±587 μm^2, with a wide range of variation (539 to 3742 μm^2). The area occupied by interstitial space amounted to 35.6±8.3%, and the specific area taken by interstitial adipocytes was 3.4±2.8%. The average number of capillaries per muscle fiber was 2.7±0.7. The light micrographs depicted in Figure 2 document these morphometric data. Fiber size varied considerably within individual subjects, and also the presence of some angulated fibers was noted (Fig. 2A). Many samples showed an enlarged interstitial space filled with connective tissue and adipocytes (Fig. 2B,C), and some muscle fibers appeared damaged or necrotic (Fig. 2C). The ultrastructural appearance (Fig. 3) spoke in favour of some typical age-related alterations of muscle like an accumulation of connective tissue in the interstitial space (Fig. 3A), small intermyofibrillar mitochondria and accumulating lipid droplets (Fig. 3B), and some disarrangement of the myofibrils (Fig. 3C).

The correlations between independent and dependent variables are placed in Table 3; age did not correlate with radiographic parameters and evidenced a small, yet significant, correlation with the space occupied by interstitial space ($r=0.34$, $p<0.05$); the daily physical activity evidenced a correlation with the lateral and superior JSW at both hips (with higher coefficients in the operated hip), and with muscle fiber area ($r=0.35$, $p<0.05$); the past physical activity showed a correlation with lateral JSW at the operated hip ($r=-0.41$, $p<0.05$) without influence on muscle data; the pain score of the Lequesne Index for each hip joint revealed high correlations with the degree of articular degeneration and also presented a negative correlation with muscle fiber area ($r=-0.32$).

Comparing the histological data with the radiographic data of both hips (Tab. 4), significant correlations ($p<0.05$) were found at the contralateral (non-operated) hip between muscle fiber size with the Kellgren index ($r=-0.33$), and also with the minimal ($r=0.43$), lateral ($r=0.50$), superior ($r=0.41$) and total JSW ($r=0.49$). At the ipsilateral hip joint, significant correlations

($p<0.05$) were only observed between muscle fiber size and lateral ($r=0.38$) and total JSW ($r=0.32$). No correlation was observed between capillaries per fiber or interstitial adipocytes and radiographic parameters of hip OA.

Discussion

The subjects of this study were averagely almost 70 years old and showed varying degrees of OA at both hips; as it could be expected for older subjects (Sirca and Susec-Michieli, 1980; Doherty, 2003) and even more for older OA patients (Martin et al., 1990), their gluteus medius muscles were composed of relatively small muscle fibers. Since skeletal muscle has a high susceptibility to the aging process, undergoing progressive and deleterious changes associated with structural disorganization and functional decline (Porter et al., 1995), it is not surprising that in our sample the muscle morphology and ultrastructure evidenced typical signs of senescent atrophy (Porter et al., 1995; Doherty, 2003). However, the limited age variation of our sample (between 42 and 83 years) does not appear to indispensably aggravate the amplitude of degenerative progression of hip OA or muscle fiber atrophy, since neither any radiographic sign of OA nor muscle fiber size significantly correlated with age. Consequently, in our study, aging itself does not explain the correlation values observed between GM histological data and the radiographic findings in both hips. The only structural feature showing a positive, yet small, correlation with age was the gluteus medius interstitial space, speaking in favour of a progressive decrease in active whole muscle mass with age in our sample (Porter et al., 1995; Doherty, 2003).

Comparing actual levels of physical activity with those described immediately before the beginning of clinical symptoms, a significant decrease of this parameter (approximately 61%) in a short period of time (between 2 and 5 years) is evident. According to the correlations described in Table 3, patients with a narrowed JSW and a structurally weaker GM, were currently less physically active, which simply may be the result of OA functional impairment. In fact, the negative correlation observed between articular pain score and gluteus medius fiber areas as well as the correlations of daily physical activity with radiographic degenerative parameters and gluteus medius fiber areas support the concept that muscle fiber atrophy may be, at least in part, the consequence of disuse induced by pain.

The finding that a weak ipsilateral GM accompanied the radiographic degenerative changes would favour the idea that all components of and around a joint undergo consequently pathological alterations. However, it is important to note that only the lateral and overall JSW show a significant but slight correlation with muscle fiber size. Moreover, the past physical activity evidenced a correlation with the lateral JSW measurements of the operated hip, reinforcing the association with mechanical overload and joint space narrowing in this region (Genda et al., 2001). This correlation, as well as the one found between mean GM fiber area and OA degree, may be explained by the walking biomechanical changes that frequently take place in OA hip. As already outlined, the gluteus medius muscle is of crucial importance for hip abduction and for pelvic stabilization during walking. When the body weight is only supported by one leg during walking, the center of gravity moves laterally concerning the supporting leg, which requires the ipsilateral abductor muscles to develop more force to maintain pelvic stabilization; if these muscles, especially the GM, are not sufficiently strong, such will result in the typical gait pattern, the "Trendelenburg gait" (Pauwels, 1980; Kapandji, 1996; Watelain et al., 2001). This Trendelenburg gait, with drop of the opposite hip due to the abductors deficit during unipodal walking, leads to adduction of the ipsilateral hip, moving the compressive force laterally to the acetabulum (Shmalzried, 1994; Sutherland, 1999). However, this pelvic drop is frequently avoided by the patients by bending the trunk, shifting the body gravity centre closer to the load bearing hip ("abductor lurch") and thus compensating the abductors deficit (Pauwels, 1980; Neumann et al., 1992; Kapandji, 1996; Watelain et al., 2001). This posture alteration shifts the body mass to the deficit side, and causes the acceleration of the body mass and consequently mechanical shock impact to the contralateral hip during weight transfer; the higher this acceleration and subsequent mechanical shock, the higher the abductor strength deficit will be, since these muscles should, under normal conditions, ensure a smooth load transfer by their eccentric contraction (Winter, 1991; Watelain et al., 2001). In a normal hip, the strong and eccentric contraction of the abductors would avoid this mechanical shock, assuring a smooth load transfer (Genda et al., 2001). Thus, these gait biomechanical alterations, the "Trendelenburg sign" and the "abductor lurch", can help to explain respectively the correlations found between past physical activity and the lateral JSW of ipsilateral hip and between GM atrophy and the OA degree of the contralateral hip.

Although the radiological signs for OA were less pronounced in the non-operated hip, almost all showed significant correlations with muscle fiber size. Gluteus medius muscles with increasing degrees of atrophy were therefore associated with more severe OA signs of the contralateral hip joint. The picture emerged from these data that the weaker the abductor muscle was, the greater OA signs were, especially at the contralateral hip. Considering the higher correlations observed between GM fiber area and contralateral radiographic signals of OA and since it cannot be assumed that functional impairments or pain of contralateral OA hip would harm more intensively the analyzed GM comparatively to the ipsilateral OA, it could be speculated that atrophy of abductor muscles fibers should be of etiological importance for the development of contralateral hip OA, the maintenance of GM structure and function being crucial for the prevention of hip osteoarthritis.

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Table 1. Radiographic characteristics of the sample: Kellgren Index and joint space width (JSW) in operated and non-operated hip joints. Values are means ± standard deviations.

Radiographic parameters	Operated hip	Non-operated hip	p value
Kellgren Index	3.1±0.8	2.2±0.9	0.000
Minimal JSW (mm)	1.6±1.5	2.9±1.2	0.000
Lateral JSW (mm)	2.7±1.9	3.8±1.7	0.000
Superior JSW (mm)	2.5±1.7	3.5±1.1	0.001
Axial JSW (mm)	3.2±1.4	4.0±1.0	0.001
Total JSW (mm) (Lateral+Superior+Axial)	8.3±3.8	11.3±3.3	0.000

Table 2. Histological morphometric results from *gluteus medius* muscle of the operated hip.

	Mean ± SD	Range
Mean fiber area (μm^2)	1448±587	539 - 3742
Capillaries per fiber (number/fiber)	2.7±0.7	1.3 - 4.2
Interstitial space (%)	35.6±8.3	22.7 - 56.6
Interstitial adipocytes (%)	3.4±2.8	0 - 10.7

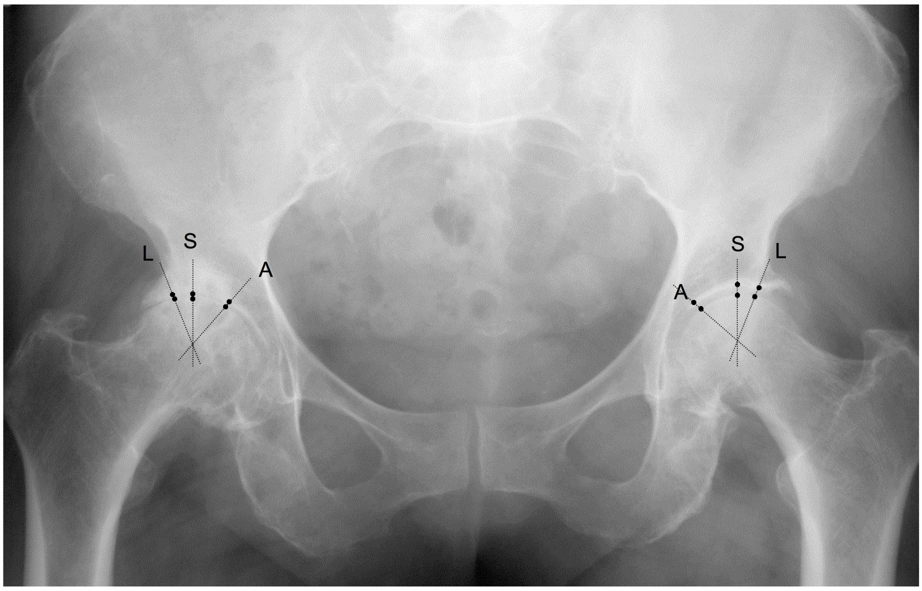

Fig. 1: Supine anteroposterior pelvic X-ray showing articular degenerative signals affecting both hips with different intensities; in both hip joints are depicted the locations for JSW measurement: Lateral (L), superior (S), and axial (A).

Table 3. Pearson correlations between independent [age, daily and past physical activity (PA), and pain scores (Lequesne Index)] and dependent variables [Kellgren Index, joint space width (JSW), and muscle morphometry parameters]. (* p<0.05).

Dependent variable	Age	Daily PA	Past PA	Pain score
Kellgren Index				
Operated hip	-0.25	-0.11	0.23	**0.57***
Non-operated hip	0.17	-0.06	0.11	**0.50***
Minimal JSW				
Operated hip	0.07	0.26	-0.24	**-0.57***
Non-operated hip	-0.15	0.16	-0.03	**-0.70***
Lateral JSW				
Operated hip	0.11	**0.38***	**-0.41***	**-0.54***
Non-operated hip	-0.14	**0.33***	-0.09	**-0.61***
Superior JSW				
Operated hip	0.09	**0.51***	-0.18	**-0.53***
Non-operated hip	-0.19	**0.33***	0.08	**-0.71***
Axial JSW				
Operated hip	-0.19	0.01	-0.09	-0.30
Non-operated hip	-0.27	-0.02	-0.03	**-0.49***
Total JSW				
Operated hip	0.03	**0.42***	-0.30	**-0.63***
Non-operated hip	-0.22	0.28	-0.03	**-0.71***
Mean fiber area	-0.24	**0.35***	-0.11	**-0.32***
Capillaries per fiber	-0.30	0.23	0.10	-0.15
Interstitial space	**0.34***	-0.10	-0.20	-0.00
Interstitial adipocytes	0.04	-0.18	-0.16	-0.12

Table 4. Pearson correlation coefficients between the *gluteus medius* histological morphometric data and the radiographic parameters in operated (ipsilateral to *gluteus medius*) and non-operated (contralateral to *gluteus medius*) hip joints. (* p<0.05).

	Hip joint	Mean fibre area	Capillaries per fiber	Interstitial space	Interstitial adipocytes
Kellgren	Operated	-0.02	0.20	-0.10	-0.18
	Non-operated	**-0.33***	-0.06	0.22	-0.07
Minimal	Operated	0.26	-0.02	0.05	0.14
	Non-operated	**0.43***	0.12	-0.19	0.10
Lateral	Operated	**0.38***	0.16	-0.07	0.04
	Non-operated	**0.50***	0.20	**-0.31***	-0.05
Superior	Operated	0.19	0.02	0.07	0.08
	Non-operated	**0.41***	0.17	-0.18	0.04
Axial	Operated	0.11	0.15	-0.10	-0.07
	Non-operated	0.29	0.15	-0.13	0.11
Total	Operated	**0.32***	0.15	-0.04	0.03
	Non-operated	**0.49***	0.21	-0.26	0.02

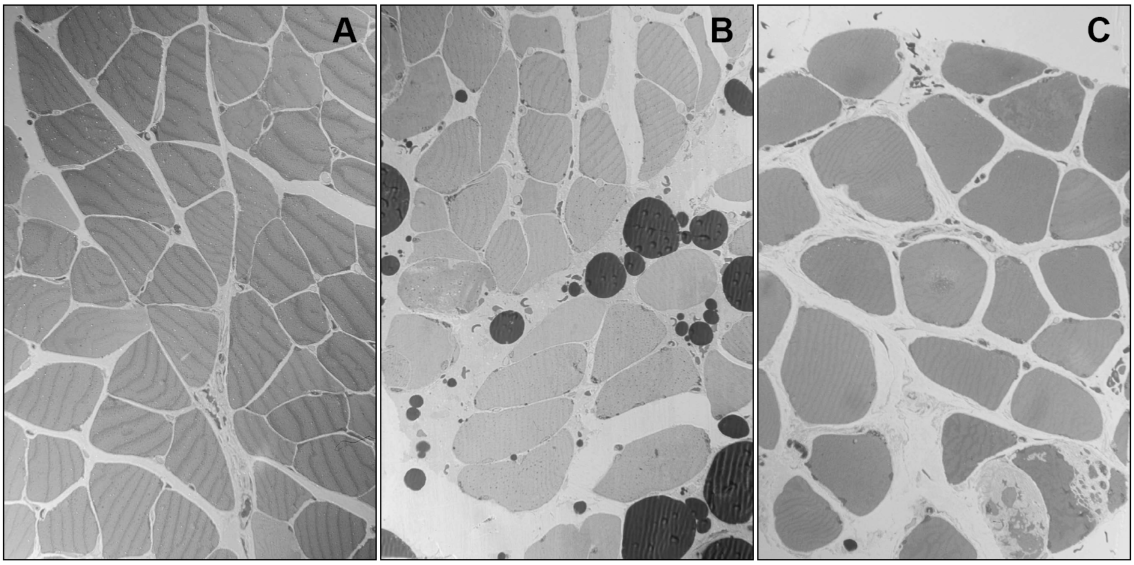

Fig. 2 - Light micrographs of the gluteus medius of an OA patient showing: in **A**, the marked heterogeneity of the muscle fibers, both in size as in shape, as well as numerous angullated muscle fibres and apparently normal interstitial space; in **B**, heterogenous and angullated fibres, together with enlarged interstitial space with connective tissue depots and adipocytes infiltration; in **C**, evidently enlarged interstitial space as well as damaged fibres (original magnification: **A**-x640; **B**-x640; **C**-x640).

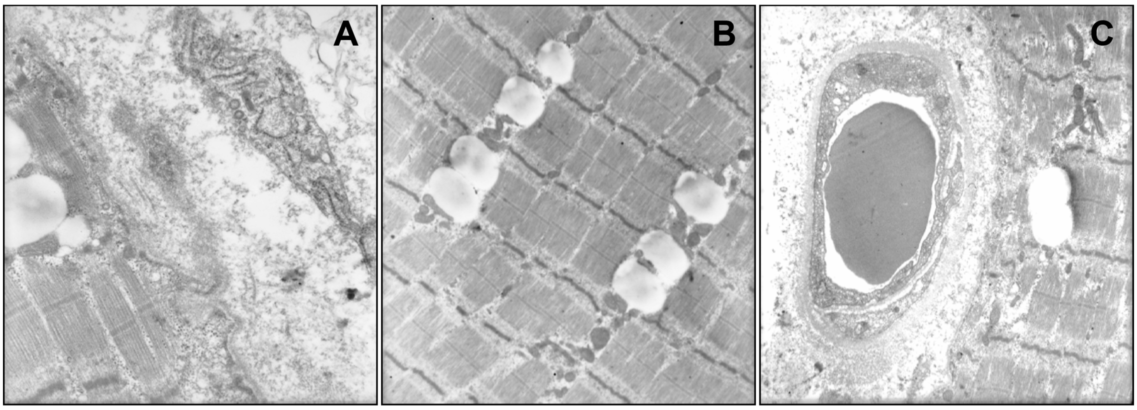

Fig. 3 – Transmission electron micrographs of the gluteus medius of an OA patient showing in **A** a muscle fiber with lipid droplets and a fibroblast with activation signs; in **B**, myofibril with regular striated pattern and small mitochondria with surrounding lipid droplets; in **C** capillary with marked enlargement of the basal membrane and muscle fibre with lipid droplets (original magnification: **A**-x20,000; **B**-x10,000; **C**-x10,000).

Legends of Figures and Tables:

Figure 1 - Supine anteroposterior pelvic X-ray showing articular degenerative signals affecting both hips with different intensities; in both hip joints are depicted the locations for JSW measurement: Lateral (L), superior (S), and axial (A).

Figure 2 - Light micrographs from cross sections of gluteus medius muscles of patients with hip joint osteoarthritis submitted to surgery for total hip joint replacement; A: the muscle fibers are heterogeneous in size and shape, especially angulated fibers can be noted; B: a muscle sample with an enlarged interstitial space, which in part is occupied by adipocytes; C: muscle sample with an enlarged interstitial space containing connective tissue, note damaged fibers in the lower right corner.

Figure 3 - Transmission electron micrographs from gluteus medius muscles of patients with hip joint osteoarthritis submitted to total hip joint replacement surgery; A: the muscle fiber contains several lipid inclusions and the fibroblast in the interstitial space appears activated; B: abundant lipid inclusions and small mitochondria in a muscle fiber with a well maintained myofibrillar arrangement; C: loss of myofibrillar arrangement, small mitochondria, and pronounced sarcoplasmic vacuolization.

Table 1. Radiographic characteristics of the sample: Kellgren Index and joint space width (JSW) in operated and non-operated hip joints. Values are means ± standard deviations.

Table 2. Histological morphometric results from gluteus medius muscle of the operated hip.

Table 3. Pearson correlations between independent [age, daily and past physical activity (PA), and pain scores (Lequesne Index)] and dependent variables [Kellgren Index, joint space width (JSW), and muscle morphometry parameters]. (* $p<0.05$).

Table 4. Pearson correlation coefficients between the gluteus medius histological morphometric data and the radiographic parameters in operated (ipsilateral to gluteus medius) and non-operated (contralateral to gluteus medius) hip joints. (* $p<0.05$).

OVERALL DISCUSSION

Biomechanical and functional changes associated with hip OA are indicative of a dynamic and tri-dimensional reality, which is difficult to evaluate; besides, radiographic images only provide a static, bidimensional and gross approach, though easier to quantify. To the insufficient information given by radiographic data, it is also necessary to associate the fact that degenerative alterations only partially explain the disability in hip joint patients (Bagge et al., 1991; Dekker et al., 1992; Dieppe, 1997).

Despite interindividual differences between signs, symptoms, functional deficits and radiographic evidences of hip OA (Lawrence et al., 1966; Birrell et al., 2000), several studies suggest a significant correlation between them, the radiographic measurement of JSW being considered the best indicator of OA clinical situation and progression (Croft et al., 1990; Scott et al., 1992; Dougados et al., 1996, 1997; Goker et al., 2000; Bierma et al., 2002); however, others have not found such marked correlation (Lawrence et al., 1989; Spector and Hochberg, 1994). In our study with hip OA patients awaiting surgery, JSW measurement of both hips was significantly correlated with Lequesne Index and ROM (study II), which agrees with previous studies suggesting stronger correlations with OA intensity (Spector et al., 1993; Birrell et al., 2001; Bierma et al., 2002). JSW is relevant due to its correlation with global pathology evolution and because it is often used as a discriminating parameter to define hip OA; however, there is still no consensus about the methodology used to measure JSW and the cut-off value at which OA should be considered (Croft et al., 1994; Spector and Hochberg, 1994). Most studies use the minimum JSW measurement (Croft et al., 1990; Birrel et al., 2001), which represents a demanding methodology because it involves the meticulous search in the whole joint space observed on the X-ray; nonetheless, JSW may be measured particularly in the supero-lateral region, the predominant cartilage loss area, matching the main load bearing area during walking (Solomon, 1976; Hodge et al., 1986; Genda et al., 2001). In the current study, the strongest correlation with hip function was found using the sum of JSW measurements obtained in three standard points (lateral, superior and axial) in the weight-bearing region (study II). This stronger correlation was seen with a global OA index such as the Lequesne Index ($r=0.67$, $p<0.05$) and also with all hip ROM measurements. In agreement to previous findings (Arokoski et al., 2004), abduction and external rotation were the ROM components that had a higher correlation with radiographic changes; although weak, flexion was significantly correlated with radiographic change degree; also internal rotation was significantly correlated with JSW, but this was weaker than with flexion. Despite our small correlations and the absence of literature consensus (Birrel et al., 2001; Arokosky et al., 2004), flexion and internal rotation are the only ROM components that continue to be used in ACR diagnosis criteria (Altman et al., 1991; Bierma et al., 1999).

On the other hand, most of the studies relating hip OA radiographic degree with ROM deficits are done with OA global Indexes, the most frequent being Kellgren's (Kellgren and Lawrence, 1957). However, this Index has been criticised because it implies a standard disease radiographic progression (Murphy and Altman, 1995) and emphasizes the presence of osteophytes (Hart and Spector, 1995b) which are considered to be part of the normal ageing process without a demonstrated correlation with hip OA radiographic and symptomatic progression (Danielsson, 1966; Dougados et al., 1996); nonetheless, in the present work (study III), CAO length was positively correlated with pain score of Lequesne Index ($r=0.38$, $p<0.05$). In literature, it is usually assumed that the joint capsule thickening along with condro-osteophyte growth and remodelling may have a role in ROM deficit (Klippel and Dieppe, 1997; Neuman et al., 2003), yet their importance and the way ROM is limited by these factors are unknown. The results of our study suggest that CAO may be an impact point for the femur neck and thus limit abduction (study III). Thus, the maximal passive abduction was correlated with CAO length ($r=-0.50$, $p<0.01$) and stronger with the free-angle limitation ($r=0.60$, $p<0.01$). As already described, free-angle is located between the femoral neck and lateral extremity of CAO, with its apex at the centre of the femoral head. Depending on the different types of pelvis, the same CAO length will have a different effect in limiting the free-angle and thus limiting the abduction. This can be similar to what happens in the femoroacetabular impingement, when repetitive microtrauma at maximal flexion can lead to *labrum* damage and acetabular chondral degeneration (McCarthy et al., 2001; Ganz et al., 2003; Guanche and Bare, 2006; Wisniewski and Grogg, 2006). So, as a result of repetitive damage, both humoral and mechanical local factors contribute to osteophyte formation, stimulating the new cartilage and bone development in the capsule and periost junction area (Aigner et al., 1995; Mow et al., 1995; Matyas et al., 1997; Felson, 1998, 2000; Uchino et al., 2000; Sandell and Aigner, 2001; Gelse et al., 2003; Blom et al., 2004). Thus, the present study suggests that repetitive microtrauma resulting from the impact in maximal hip abduction may be a factor to develop or worsen CAO. Consequently, in the future, small medical interventions to ablate or destroy osteophytes, might limit traumatic and subsequent inflammatory episodes.

On the other hand, in hip OA etiopathology it is known that inflammation, trauma, usage or excess load bearing lead the synovium and the chondrocytes to produce a series of substances, such as interleukin-1 and tumor necrosis factor; chondrocytes then increase synthesis of substances such as proteolytic enzymes, the final result of this chain being a drop in the cartilagineous matrix’s proteoglicans and structural changes of type 2 collagen (Mankin et al., 1971; Lippiello et al., 1977; Eyre et al., 1980; Pierron et al., 1990; Aigner et al., 1992, 1993; Larbre et al., 1994; Mathias et al., 1995; Sandell and Aigner, 2001); consequently, OA lesions such as fissures, cartilage wearing and subchondral bone sclerosis appear with the imbalance between synthesis and degradation of the matrix components (Poole, 1995; Walker, 1996; Sandell and Aigner, 2001). Thus, hip OA must be seen as a secondary pathology if it is a result of the adaptive response of joint to multiple aggressions in a genetic, constitutional and biomechanical specific environment (Solomon, 1984; Brandt et al., 1998). However, the triggering factors to develop hip OA may not affect adjacent joints, which support the same load as the knee joint (Felson and Zhang, 1998).

Additionally, due to direct lesion or disuse, the inflammation and subsequent pain may have deleterious repercussions both at the joint and in periarticular tissues, namely at the skeletal muscles. In the hip, abductor muscle alterations have a special importance due to their role in the pelvic stabilization during walking (Pauwels, 1980; Kapandji, 1996; Fetto et al., 2002). The few studies evaluating the relationship between muscle strength and hip OA, point out periarticular muscle strength decrease, particularly affecting abductors (Murray and Sepic, 1968; Shih et al., 1994; Arokoski et al., 2002). In fact, the dysfunction of the GM, the main hip abductor muscle, appears to be associated to hip OA evolution (Hurley, 1999; Sims, 1999; Sims et al., 2002); however, it remains to be determined whether this GM dysfunction is a primary factor for the development of hip OA, as with the quadriceps and knee OA (Slemenda et al., 1997, 1998), or is the main consequence of osteoarthritis pain-induced disuse. In the clinical case presented in study I, no ultrastructural, morphological or biochemical evidence was found in the GM biopsy that might have led to any repercussion in degenerative radiological changes of the hip; in this case, the patient did not have clinical hip OA according to the ACR criteria (Altman et al., 1991), exhibiting some signs of radiological OA (grade 2 of Kellgren), but without any symptoms. The patient also showed a normal balance in the composition of type I and II GM heavy myosin isoforms, almost equally represented. However, considering the diversity and multifactorial etiology of this disease (Felson et al., 2000; Rogers et al., 2004), it can only be concluded that in this particular case (study I) hip OA radiographic changes were mainly triggered by other causes rather than by GM dysfunction.

Moreover, a selected atrophy (number and size) of type II muscle fibres has been shown in GM of hip OA patients (Sirca and Susec-Michieli, 1980; Martin et al., 1990; Nakamura and Suzuki, 1992) and in quadriceps of knee OA patients (Nakamura and Suzuki, 1992; Bade et al., 1994). However, abnormal mosaic patterns of fibre types, such as fibre type grouping and grouped atrophy of type II fibres were described in the quadriceps of knee OA patients and not in the GM of hip OA patients (Nakamura and Suzuki, 1992). These findings may suggest a motor neuron dysfunction in quadriceps of knee OA patients (Nakamura and Suzuki, 1992), but not in GM of hip OA patients (Sirca and Susec-Michieli, 1980; Nakamura and Suzuki, 1992). The involvement of the nervous system is suggested by other authors (Wyke, 1967; Gifford, 1998; Vilensky, 1998; Hurley, 1999; Sims et al., 2002). Thus, as a result of the sensoriomotor dysfunction, the muscle weakness, fatigability and proprioceptive deficits must be implicated in OA pathogenesis by the impairment of the joint protective mechanisms (Hurley, 1999). Moreover, it has been hypothesised that the relative increase of type I fibres may enhance the muscle stiffness and consequently change the joint shock-absorbing capacity turning it more susceptible to OA (O'Reilly et al., 1997).

It is already assumed that homolateral quadriceps strength deficit is a primary OA etiologic factor in knee joint, probably due to a mechanical shock absorption deficit (Slemenda et al., 1997, 1998; Felson et al., 2000). On the other hand, a recent hip OA study did not find correlation between muscle strength and hip pain severity, although the pain scores immediately prior to muscle testing were higher for the most affected hip compared to the other side (Arokoski et al., 2002); this suggests that a hip muscle weakness may be present in patients with radiographic hip OA and without hip pain. The referred study showed a significant correlation between gluteal muscle cross sectional area measured from magnetic resonance images and hip muscle strength (Arokoski et al., 2002); thus, the decrease of hip muscle size is associated with the decrease of muscle strength and particularly the abduction strength values can be correlated with radiographic hip OA changes (Arokoski et al., 2002).

Although histological studies of GM in humans are scarce, they suggest a reduction of fibre diameter with ageing, more pronounced in OA patients (Sirca and Susec-Michieli, 1980; Martin et al., 1990), this atrophy being interpreted as a consequence of the decreased muscle activity. In the present work (study V), age did not show a significative correlation with mean GM fibre area in hip OA patients suggesting that other conditioning factors may have an important role in OA muscle-related atrophy. However, age showed a positive, yet small, correlation with the gluteus medius interstitial space, speaking in favour of a progressive decrease in active whole muscle mass with age (Porter et al., 1995; Doherty, 2003).

The current and past physical activity was another factor that might interfere with OA degree and muscle performance. The higher the JSW, the higher the current physical activity level, with a maximum correlation value ($r=0.51$, $p<0.05$) for the superior JSW of the hip awaiting surgery (study V), thus reinforcing the concept that JSW measurements correlate significantly with the functional deficit due to OA (study II). In this way, there are some studies where an association between hip OA and occupational activities was demonstrated (Thelin, 1990; Vingård et al., 1991a; Vingård, 1991b; Croft, 1992; Axmacher and Lindberg, 1993; Roach et al., 1994; Coggon et al., 1998; Lievense et al., 2001; Rossignol et al., 2005) and also with sport activities (Klünder et al., 1980; Andersson et al., 1989; Vingård, 1991a; Lindberg et al., 1993; Vingård et al., 1993; Schmitt et al., 2004; Hermette et al., 2006); however this association is not completely consensual (Lindberg and Danielsson, 1984; Felson, 1988; Jacobsen et al., 2004b).

In this work (study V), the past physical activity evidenced a correlation with the lateral JSW measurements of the hip awaiting surgery, suggesting an association with mechanical overload and joint space narrowing in this region. This correlation, as well as the one found between mean GM fibre area and OA degree, may be explained by the walking biomechanical changes that frequently happen in an OA hip. So, during unipodal stance and in the presence of the Trendelenburg sign, the abductor-impaired hip is in adduction, due to the drop of the pelvis to the opposite side, leading to a lateral dislocation of the compressive forces towards the acetabulum (Schmalzried et al., 1994; Sutherland et al., 1999). On the other hand, patients frequently avoid the pelvis drop towards the opposite side by leaning the body trunk and moving the gravity centre towards the load bearing hip, thus compensating abductor deficit (Pauwels, 1980; Watelain et al., 2001). As such, patients responding to abductor strength deficit with contralateral pelvis drop would have an augmented cartilage wearing-off in the lateral region of the weak hip. If the trunk bends towards this weak hip, a body mass acceleration will be experienced when the load transfers to the opposite hip during gait. The higher this acceleration and subsequent mechanical shock, the higher the abductor strength deficit will be, since these muscles should, under normal conditions, ensure a smooth load transfer by their eccentric contraction (Winter, 1991; Watelain et al., 2001).

The above referred reinforces the recommendations for the medical management of OA published by the ACR (Altman et al., 2000) and the European League of Associations of Rheumatology (Pendleton et al., 2000; Zhang et al., 2005) that include in first place the non-pharmacological modalities, such as the patient education. A meta-analysis showed that patient education could provide more pain relief than non-steroid anti-inflammatory drugs (Superio-Cabuslay et al., 1996). With this propose and similarly to "back schools", this education can be done by a "hip school" (Klässbo et al., 2003) where patients received the basic knowledge about articular protection and safety use. Other objective is to reinforce the hip muscles (Dexter, 1992; Hurley, 1999; Minnor, 1999; Van Baar et al., 1999; Hurley, 2002; Fransen et al., 2003; Zhang et al., 2005), but simultaneously to avoid mechanical overload and to prevent repetitive (micro) trauma. Additionally, the stretching exercises can increase flexibility and consequently the maximal joint ROM (Wiktorsson et al., 1983; Magnusson, 1998), namely the abduction after adductor muscle stretching (Leivseth et al., 1989); the passive muscle stretching can also lead to a significant increase of muscle fibre cross-sectional area (Leivseth et al., 1989; Van Baar et al., 1999). Thus, the principal objectives of the management of a patient with hip OA are to control pain, limit the functional impairment and modify the dynamic process of the pathophysiology (Doherty and Dougados, 2001).

Although surgical treatment with THR is an important advance in hip OA treatment and a current practice in most Orthopaedic Departments (NIH Consensus Conference 1995; Altman et al., 2000; Zhang et al., 2005), post-surgery functional results are insignificant for a large number of patients (Gore et al., 1977; Brown et al., 1980; Borja et al., 1985; Skinner, 1993; Nilsdotter et al., 2003). Abductor muscle strength was shown to be weaker in patients with hip arthroplasty than in patients with hip OA (Murray and

Sepic, 1968). In these THR subjected patients, the existence of an abductor mechanical dysfunction may be associated with intrinsic strength deficit or biomechanical parameter alterations due to surgery (McGrory et al., 1995; Downing et al., 2001; Asayama et al., 2002).

Some studies suggest the Trendelenburg test as a hip abductor function indicator (Hardcastle and Nade, 1985; Pai, 1996; Downing et al., 2001) and maximal active abduction (degrees) as a parameter to be used in evaluating post-THR abductor muscle function (Mallory, 1974; Romero et al., 2001). In the present study, despite a positive correlation tendency between these two parameters with results from post-surgery radiographic evaluation of abductor biomechanics, this was not significant (study IV); however, with time of maximal active abduction (seconds), this correlation was significant, suggesting that the two mentioned parameters should be complemented by the measured period in holding positions to evaluate both strength and fatigue of abductor muscles.

It is known that the shortening of the abductor muscle lever arm increases the strength required for abductor moment generation that balances body weight during unipodal stance (Johnston et al., 1979; Pauwels, 1980; Delp et al., 1996). In the current study we also found a relationship between abductor lever arm measured in post-surgery radiograph and hip abductor function in THR patients (study IV); this association had already been established in previous studies (McGrory et al., 1995; Romero et al., 2001; Asayama et al., 2002), despite not confirmed by other older studies (Gore et al., 1977; Borja et al., 1985). On the other hand, abductor muscle length measured in the post-surgery radiograph did not correlate significantly with hip abductor function (study IV), which does contradict some previous studies that suggest such positive correlation (Gore et al., 1977; Borja et al., 1985); however this correlation is also presented as a more complex or even a negative one (Wiesmann et al., 1978; Borja et al., 1985). The hip dysfunctional index (DI) associated with these two parameters (DI = length of abductor muscles x lever arm) had an even higher correlation ($r=0.63$, $p<0.05$) than the lever arm ($r=0.61$, $p<0.05$) with the time of maximal active abduction. Thus, this result reinforces the DI as a radiographic representative mark of hip abductor torque (Romero et al., 2001) and draws attention to the importance of its determinant parameters under the surgeon's control at the moment of prosthesis placement (Borja et al., 1985).

After the conclusion of this part of the work (study IV) and after looking at histological results of GM biopsies performed in sample studied, we found that histological parameters, particularly mean fibre diameter, did not exhibit significant correlations with post-surgery functional results (maximal active abductions and times of sustained maximal active abduction and Trendelenburg position). Thus, post-surgery results were more affected by radiographic biomechanical parameters related to abductor muscle functionality than to GM intrinsic characteristics.

Concluding remarks

All the results presented throughout this work should lead us to suggest new approaches to hip OA patients in order to: i) implement preventive measures for joint economy, avoiding mechanical overload; ii) prevent repetitive traumatic movements that require maximal hip ranges, especially during abduction; iii) strengthen the periarticular muscles, particularly bilateral hip abductors; iv) implement a new approach to radiographic diagnosis, namely with JSW measurements in standard locations, giving also attention to other degenerative alterations, such as osteophytes; v) develop strategies for osteophytes ablation or destruction in selected cases or, in cases where surgery is imperious due to patients' living standards alteration, vi) take particular care in the selection of prosthesis type and measurements of its components, using the contralateral hip radiographic geometry as a comparing model.

CONCLUSIONS

Considering the results of the present study, it is possible to formulate the following conclusions:

1. The sum of the joint space width in three standard locations (lateral, superior and axial), when comparing to each one solely, better reflects functional status in the hip osteoarthritis and should be used in future studies as a predictive value of hip function or as an estimate of the remaining cartilage in the load bearing area of the joint.

2. The hip passive range of motion, and particularly the abduction, is a sensitive marker of radiographic severity of joint space narrowing in weight-bearing area and of radiographic length of cranial acetabular osteophytes.

3. The radiographic cranial acetabular osteophytes length and abductor free-angle are associated with abduction limitation, due to the impact of the femoral neck against the superior acetabular osteophytes extremity. Therefore, gestures and activities evolving maximal hip abduction should be avoided in order to attenuate the traumatic aggression and, probably, OA progression.

4. *Gluteus Medius* fibre atrophy is associated with the degree of radiographic degenerative changes of both hips; this correlation was particularly stronger with the radiographic changes of the contralateral hip, which may be explained by the mechanical shock impact during the load transfer to the

opposite leg and reinforces the hypothesis that GM dysfunction may be a conditioning factor for hip OA development.

5. Joint space width for OA hips awaiting total hip replacement is associated with current physical activity level, but only the lateral joint space width is associated with past physical activity score. This fact may signal the lateral dislocation of compressive forces when the pelvis drops to the opposite side due to abductor strength deficit, in walking unipodal stance (Trendelenburg sign).

6. Patients' results of post-surgery abductor function (over 6 months after total hip replacement) were related to radiographic dysfunctional index, in particular the lever arm of the abductor muscles. The choice of prosthesis type and dimensions of its components are determinant to post-surgery functional results.

7. This thesis reinforces the necessity of further investigation in order to test the importance of hip biomechanical acute and chronic alterations as essential conditioning factors to OA development and, consequently, to the improvement of therapeutic programs, implant design or reconstructive surgery plan.

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APPENDICES

Clinical evaluation protocols

Radiographic evaluation protocol

Clinical evaluation protocols

FUNÇÃO MUSCULAR E ARTROSE DA ANCA
AVALIAÇÃO CLÍNICA

EXAME Nº:________ Data(Ex.): ____/____/____; Data (Cir.):____/____/____

Nome:____ Procº Nº __________

DIAGNÓSTICO:________________________________ Data (Iníc.): ____/____/____

I – DADOS DEMOGRÁFICOS

Idade: ______ Data de Nascimento: ______ / ______ / ______

Sexo: M ____ Raça: ____Caucasiana

F ____ ____Outra: ______________________

Peso: __________ Kg Altura: ___________ cm

Profissão: _______________________________

II – HISTÓRIA CLÍNICA E EXAME FÍSICO

	Anca Direita		Anca Esquerda	
1. Dor	S ____	N ____	S ____	N ____
Em mais de metade dos dias do mês anterior	S ____	N ____	S ____	N ____
Local da dor:				
Nádega	S ____	N ____	S ____	N ____
Virilha	S ____	N ____	S ____	N ____
Face anterior da coxa	S ____	N ____	S ____	N ____
Joelho	S ____	N ____	S ____	N ____
Quando ocorre a dor (LEQUESNE)				
Nocturna:				
- Com os movimentos ou posturas	____		____	
- Mesmo imóvel	____		____	
No início da manhã:				
- Durante alguns minutos	____		____	
- Durante mais de 15 minutos	____		____	
Na posição de pé ou com o "bater de pés"	____		____	
Na marcha				
- Somente após alguma distância	____		____	
- Desde os 1ºs passos e de forma crescente	____		____	
Desconforto na posição sentado prolongada	____		____	

2. Claudicação / Marcha

	Anca Direita	Anca Esquerda
2.1 Claudicação (Coxear)		
Nenhuma	_____	_____
Ligeira	_____	_____
Moderada	_____	_____
Impossível a marcha	_____	_____

2.2 Sinais específicos da anca

	Anca Direita	Anca Esquerda
Inclinação lateral do tronco	_____+	_____+
	_____-	_____-
	_____ Impossível testar	_____ Impossível testar
Sinal de Trendelenburg	_____+	_____+
	_____-	_____-
	_____ Impossível testar	_____ Impossível testar

2.3 Suportes / Ajudas

Nenhuma	_____	
1 bengala / Marchas longas	Lado direito _____	Lado esquerdo _____
1 bengala / sempre	Lado direito _____	Lado esquerdo _____
1 muleta / canadiana	Lado direito _____	Lado esquerdo _____
2 bengalas	_____	
2 muletas / canadianas	_____	
Impossível a marcha	_____	

2.4 Marcha máxima

Ilimitada	_____
Mais de 1 km, mas limitada	_____
Aproximadamente 1 km (cerca de 15 minutos)	_____
500 a 900 metros (8 a 15 minutos)	_____
300 a 500 metros	_____
100 a 400 metros	_____
Menos de 100 metros	_____

3. Avaliação funcional (LEQUESNE)

Escadas (subir/descer 3 andares)

Sem dificuldade	_____
Possível com dificuldade	_____
Incapaz	_____

Calçar sapatos ou meias

Sem dificuldade	_____ Dtª	_____ Esqª
Possível com dificuldade	_____ Dtª	_____ Esqª
Incapaz	_____ Dtª	_____ Esqª

Apanhar um objecto do chão

Sem dificuldade	_____
Possível com dificuldade	_____
Incapaz	_____

Sair de um carro

Sem dificuldade	_____
Possível com dificuldade	_____
Incapaz	_____

4. Grau de mobilidade (Goniómetro)

	Anca Direita	Anca Esquerda
Flexão permanente ("Flexo")	_____	_____
Flexão	_____	_____
Extensão	_____	_____
Abdução	_____	_____
Adução	_____	_____
Rot. Extª	_____	_____
Rot. Intª	_____	_____
	Joelho Direito	**Joelho Esquerdo**
Flexão	_____	_____
Extensão	_____	_____

5. Força muscular

	Anca Direita	Anca Esquerda
Flexores	_____	_____
Extensores	_____	_____
Abdutores	_____	_____
Adutores	_____	_____
Rotadores Externos	_____	_____
Rotadores Internos	_____	_____
	Joelho Direito	Joelho Esquerdo
Quadricípete	_____	_____
Isquiotibiais	_____	_____

6. Comprimento dos membros inferiores

	Direito	Esquerdo
Aparente (Umbigo – Maléolo interno)	_____	_____
Real (EIAS – Maléolo interno)	_____	_____

7. Medida do afastamento intermaleolar (interno) __________

III – ANTECEDENTES

1. Antecedentes pessoais

Artroses (segmentos) ____

____

Traumatismos (Tipo/local) ____

____

Cirurgias: histerectomia S ____ N ____ Data ___/____/___

Outras: ____

Osteoporose: Desconhece: ______ N ____

S ____ Medicação: ___________________

Diabetes: Desconhece: ______ N ____

S ____ Medicação: ___________________

Hipertensão: Desconhece: ______ N ____

S ____ Medicação: ___________________

Hiperuricémia: Desconhece: ______ N ____

S ____ Medicação: ___________________

Outras patologias ____

____

Hábitos tabágicos N ____ S ____ Desde _________

2. Tratamentos

AINES N ____ S ____

Uso regular (>= 5x/semana) N ____ S ____ Nº meses/ano: ______

Outros fármacos ____

Tratamentos não farmacológicos N ____ S ____

(Nº meses/ano)

Agentes Físicos ___________________

Cinesioterapia/exercícios ___________________

Hidroterapia ___________________

IV – EXAMES SUBSIDIÁRIOS

1. Rx

Anca direita ____

Anca esquerda ____

2. VS:

________ mmHg Data: ____/___/___

ÍNDICE DE OSTEOARTRITE (WOMAC)

ARTICULAÇÃO AVALIADA

	Esq.	Dir.
Anca	_____	_____
Joelho	_____	_____

SECÇÃO A – DOR

INSTRUÇÕES: as perguntas seguintes dizem respeito ao grau de dor que sente actualmente devido a artrose das ancas ou joelhos. Para cada situação refira a intensidade da dor experimentada recentemente.

Pergunta: Qual é a intensidade da dor que sente?

	Nenhuma	Leve	Moderada	Severa	Máxima
1. A caminhar numa superfície plana	_____	_____	_____	_____	_____
2. A subir ou descer escadas	_____	_____	_____	_____	_____
3. Durante a noite na cama	_____	_____	_____	_____	_____
4. Sentado ou deitado	_____	_____	_____	_____	_____
5. De pé (parado)	_____	_____	_____	_____	_____

SECÇÃO B – RIGIDEZ NA ARTICULAÇÃO

INSTRUÇÕES: As questões seguintes dizem respeito ao grau de rigidez da articulação (não dor) que tem sentido recentemente nas ancas ou nos joelhos. Rigidez é a sensação de limitação ou dificuldade em iniciar o movimento das articulações.

	Nenhuma	Leve	Moderada	Severa	Máxima
1. Qual o grau de rigidez ao acordar (de manhã)?	_____	_____	_____	_____	_____
2. Qual o grau de rigidez após estar sentado, deitado ou em repouso no fim do dia?	_____	_____	_____	_____	_____

SECÇÃO C – FUNÇÃO FÍSICA (DIFICULDADE NAS ACTIVIDADES DIÁRIAS)

INSTRUÇÕES: As questões seguintes dizem respeito à sua função física, isto é, a sua capacidade para se movimentar e tratar de si próprio. Para cada uma das actividades seguintes indique o grau de dificuldade que sente actualmente devido à artrose das ancas ou joelhos.

Pergunta: Qual é o grau de dificuldade que sente?

	Nenhuma	Leve	Moderada	Severa	Máxima
1. Descer escadas	_____	_____	_____	_____	_____
2. Subir escadas	_____	_____	_____	_____	_____
3. Levantar-se (da posição de sentado)	_____	_____	_____	_____	_____
4. Manter-se de pé	_____	_____	_____	_____	_____
5. Dobrar-se para o chão	_____	_____	_____	_____	_____
6. Andar numa superfície plana	_____	_____	_____	_____	_____
7. Entrar e sair de um carro	_____	_____	_____	_____	_____
8. Ir às compras	_____	_____	_____	_____	_____
9. Calçar meias (ou vestir collants)	_____	_____	_____	_____	_____
10. Levantar-se da cama	_____	_____	_____	_____	_____
11. Descalçar meias (ou collants)	_____	_____	_____	_____	_____
12. Estar deitado na cama	_____	_____	_____	_____	_____
13. Entrar e sair do banho	_____	_____	_____	_____	_____
14. Permanecer sentado	_____	_____	_____	_____	_____
15. Sentar-se e levantar-se da sanita	_____	_____	_____	_____	_____
16. Fazer trabalhos domésticos pesados	_____	_____	_____	_____	_____
17. Fazer trabalhos domésticos leves	_____	_____	_____	_____	_____

QUESTIONÁRIO DE ACTIVIDADE FÍSICA

(Health Insurance Plan of New York Questionnaire)

ACTIVIDADE FÍSICA (NO TRABALHO)

Pergunta	Resposta	Peso Atribuído	Actual/ (desde ______)	19___ a ______
1. Tempo passado sentado (no trabalho)	Praticamente todo o tempo Mais de metade do tempo Cerca de metade do tempo Menos de metade do tempo Quase tempo nenhum	0 1 2 3 4		
2. Tempo passado a caminhar (no trabalho)	Quase tempo nenhum Menos de metade do tempo Cerca de metade do tempo Mais de metade do tempo Praticamente todo o tempo	0 1 2 3 4		
3. Caminhar de casa para o trabalho e do trabalho para casa	Nenhum quarteirão ou < 1 quarteirão 1 ou 2 quarteirões (>=80m <240m) 3 ou 4 quarteirões (>=240m <400m) 5 a 9 quarteirões (>= 400m <800m) 10 a 19 quarteirões (>= 800m <1600m) 20 a 39 quarteirões (>=1600m < 3200m) 40+ quarteirões (>= 3200 m))	0 1 2 3 4 5 6		
4. Levantar ou transportar coisas pesadas	Raramente ou nunca Às vezes Frequentemente	0 3 6		
5. Meio de Transporte para o trabalho e do trabalho para casa	Nenhum Carro, autocarro, comboio ou barco Bicicleta * Bicicleta* e um ou mais meios de transporte	0 1 2 3		

6. Horas passadas no trabalho	Menos de 25 25 – 34 35 - 40 41 – 50 51+	1 2 3 4 5		

ACTIVIDADE FÍSICA (FORA DO TRABALHO)

Item	Frequentemente	Às vezes	Raramente ou nunca	Actual/ (desde _____)	19___ a _____
7. Faz caminhadas com tempo bom	2	1	0		
8. Faz trabalhos em casa ou no apartamento	2	1	0		
9. Faz jardinagem na Primavera ou no Verão	2	1	0		
10. Participa em desportos; Jogo activo com bola exceptuando o golfe, bowling, pólo ou bilhar	4	3	0		
11. Outro	3	2	0		

*Adaptação feita para a população em estudo (Cidade e Distrito de Aveiro), o original é "Metropolitano" (Nova Iorque)

Radiographic evaluation protocol

- Atlas of individual radiographic features in osteoarthritis – Altman et al.

Rx - Data ____/____/____

ANCA _______	Normal	Grau 1	Grau 2	Grau 3
I . Diminuição da Entrelinha Articular a) Superior				
b) Axial				
II. Quistos Subcondrais a) Acetabulares				
b) Femorais				
III. Osteófitos a) Acetabulares Superiores				
b) Femorais Superiores				
IV. Esclerose Subcondral a) Acetabular				
b) Femoral				
V. Contraforte Femoral				