Sport activity after hip arthroplasty

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ABBREVIATIONS

THR: Total Hip Replacement

PMMA: PolyMethylMethAcrylate

HR: Hip Resurfacing

CAS: Computer-Assisted Surgery

PAL: Physical Activity Level

TEE: Total Energy Expenditure

BMR: Basal Metabolic Rate

DLW: Doubly Labelled Water

FAO: Food and Agriculture Organization

WHO: World Health Organization

ONU: Organisation des Nations Unies

TJA: Total Joint Arthroplasty

THA: Total Hip Arthroplasty

HS: Hip Society

AAHKS: American Association of Hip and Knee Surgeons

ROM: Range Of Motions

ADL: Activities of Daily Living

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1. **SUMMARY**

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There has been a significant increase in the number of total hip replacements performed throughout the world during the past 20 years. Hip replacements were originally designed for elderly people, generally over the age of 70, who had a sedentary lifestyle, and who were not expected to outlive the lifetime of the prosthesis. The ability of these artificial joints to maintain everyday activity and to relieve pain has been a revolution in the treatment of arthritic conditions, and we would expect a new hip joint in these elderly patients to be good for 15 to 20 years.

As demand for total hip replacement increases, patients are going through surgical procedures at younger ages and often choose to maintain an athletic level of activity after the operation. Although the technology behind joint replacement surgery continues to improve, people are pushing the implants to the limit and causing them to fail earlier, leading to the necessity of setting guidelines according to the different types of sport activities practiced after the operation. While there are numerous published guidelines on what types of activity people should do after total hip replacement, none of them are based on proper randomised control trials. There is no doubt that patients who participate in sport after hip replacements are at higher risk of traumatic complications, including dislocation, fracture around the prosthesis and failure of the implant.

Expert recommendations are available from the American Association of Hip and Knee Surgeons and the Hip Society, among others. These suggestions can be used in conjunction with a meticulous pre-operative evaluation to provide guidance for patient rehabilitation and activity post-operatively. Surgeons should also take into consideration the anatomic and biomechanical factors involved with surgical technique when providing patients with advice to make sure the stakes are well understood.

Key words: Total hip replacement, sport activity, post-operative.

2. INTRODUCTION

2.1. Operation of the century

Hip arthroplasty is one of the most famous surgical operation of the 20th century. In 2007, the venerable journal Lancet even described it as the operation of the Century.[1] The improvement brought by the operation in the quality of life of patients with disabling arthritis was so consequent that a new era of bioengineering technology started with development of hip prostheses. Since the 1960s, the benefits from the operation have reached a point where the typical patient who receives a total hip replacement (THR) can expect not only the resolution of his pain, but a near complete restoration of his quality of life, including demanding activities and the practice of various kind of different sports.

The indications for total hip arthroplasty have expanded to such an extent that this surgery is no longer performed only in the elderly or in those with debilitating hip pain, arthritis, and severe functional restrictions. A contrario, Total Hip Arthroplasty is now performed in younger and higher-demand patients, with expectations, quality-of-life measures, and intentions to return to prior activity levels that challenge surgical techniques and implant design technology. It is currently performed worldwide with similar techniques and excellent results. Despite variations in

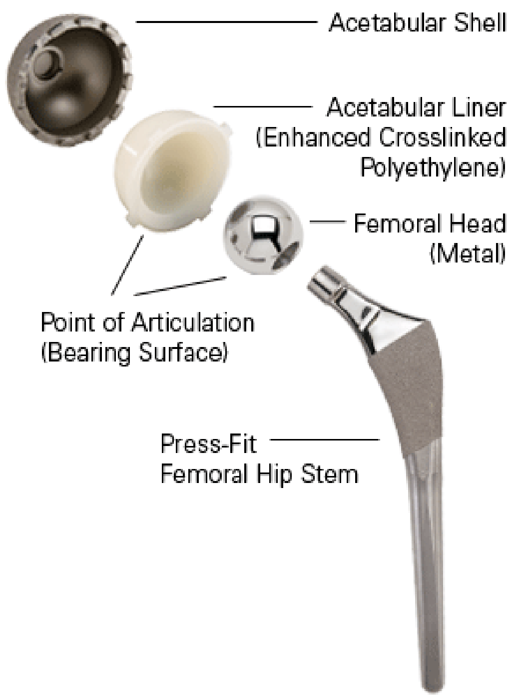

Figure 1. THR implant

technique and implant selection, medium and long-term outcome studies have demonstrated over 90% implant survival at 15 to 20 years.[2]

2.2. Prosthesis and implantation

THR implants typically consist of three parts (Fig. 1)[3] : the acetabular component (which is fitted into the acetabular pelvic bone of the patient, with or without cement), the femoral component inserted down the femoral canal, and the bearing surfaces, which are the articulating aspects of the implant.

Two different models have been driving the conception and implementation of hip prostheses: cemented and uncemented hips. (Fig. 2)[4]

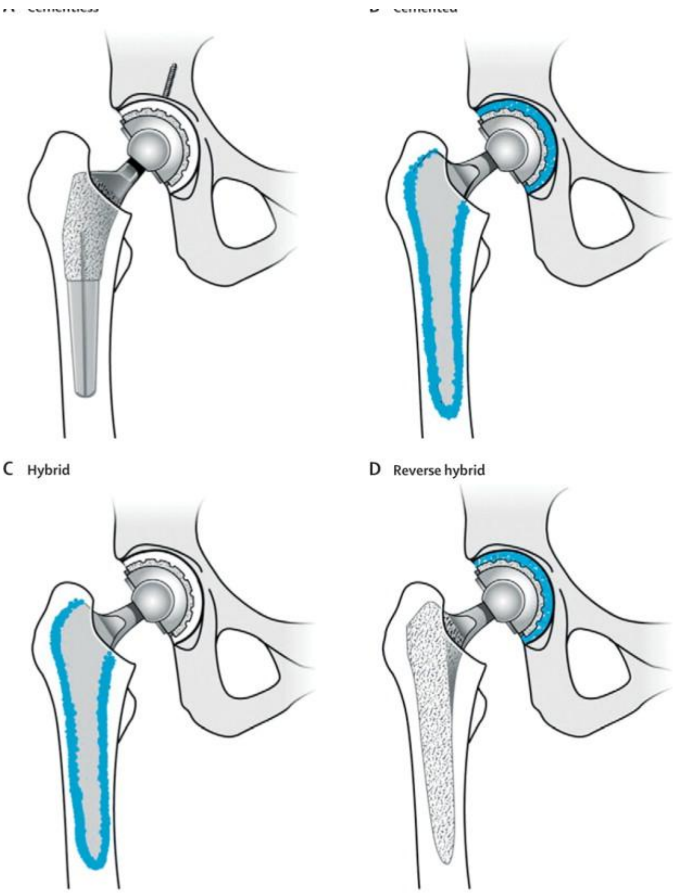

Figure 2. Overview of four different fixation options for the femoral stem and acetabular cup in total hip arthroplasty with a metal-on-polyethylene bearing surface. (A) Fully cementless design with a proximally porous coated femoral stem. (B) Fully cemented design. (C) Hybrid design with a cemented stem and cementless cup. (D) Reverse hybrid design with a cemented cup and cementless design with an extensively (fully) porous coated femoral stem.

Glück, a german surgeon, was the first researcher to use cement « for a better fixation » of both components of an ivory total knee replacement in 1891.[5] Almost 60 years later, John Charnley introduced and popularized use of polymethyl methacrylate (PMMA) bone cement for fixation of hip prostheses. Although the chemical composition of bone cement has essentially remained the same over the years, the cementation technique has changed greatly.[6]

Two group of researchers [7] [8] have shown that increased pressurization of cement enhanced penetration into bone interstices, which was associated with raised tensile and shear strengths at the bone-cement interface. The benefits of contemporary cementing techniques have been shown in the Swedish hip register[9], and very good mid-to-long term results have been published.[10]

Over the past 50 years, many improvements were made in both the materials and the methods used to insert and hold the femoral and acetabular components in place. Today, the most commonly used bone cement is still the PMMA. Even though the utilization of cement has been recently reduced, one the biggest advantage of this type of prosthesis fixation is that the patient can put full weight on the limb and walk without support almost immediately after surgery, resulting in a faster rehabilitation.

Despite the fact that cemented implants have a long track record of success, they are not ideal for everyone. Indeed, cemented fixation relies on a stable interface between the prosthesis and the cement and a solid mechanical bond between the cement and the bone. Today's metal alloy stems rarely break, but they can occasionally loosen. Two main processes are known for contributing to loosening.[11] The first one is the "fatigue fracture" which is cracks in the cement that occurs over time. The fatigue fracture occurs more often with patients who are very active or very heavy. The second process believed to contribute to loosening of the hip joint is the presence of debris. (Fig. 3)[12] The action of the metal

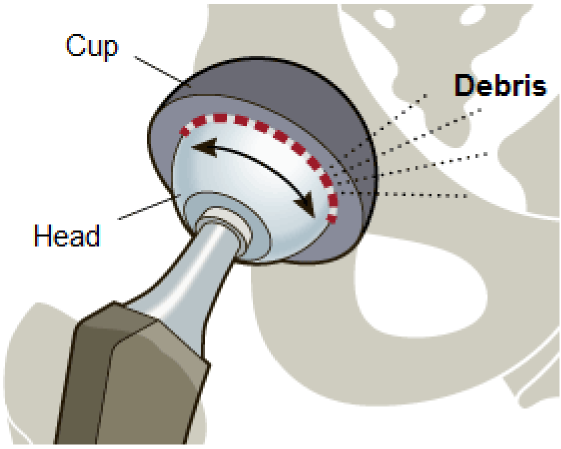

Figure 3. Polyethylene wear debris

ball against the polyethylene cup of the acetabular component creates polyethylene wear debris. The cement or polyethylene debris particles generated are then susceptible to trigger a biologic response that can further contribute to loosening of the implant and loss of the surrounding bone. The microscopic debris particles are absorbed by cells around the joint and initiate an inflammatory response from the body, which tries to remove them. This inflammatory response leads to the process of osteolysis (bone destruction and resorption) around the implant. As the bone weakens, instability increases. The loss of bone can occur around both the femur and the acetabulum, progressing from the edges of the implant. As a result, researchers who found out about the presence of the debris and the local response it initiated assumed that premature loosening of cemented components was related to so-called "cement disease".[13] [14] [15]

Despite these complications, it is generally admitted that the bond between cement and bone is reliable and durable. Cemented THR is nowadays more commonly used for patients who are less likely to put stresses on the cement and cause the fatigue fractures. These category of patients usually include patients with sedentary or light activity lifestyle (cf. table 1), like older patients, those with rheumatoid arthritis, and the younger patients with compromised health or poor bone quality or density.

Early failure of cementation was common with the first generation techniques. Based on this observation, the idea of developing prostheses which could be implanted without the use of cement emerged. Cementless femoral and acetabular components were designed to provide adequate initial stability and to encourage bone to ossointegrate into the implant. In general, these designs are larger and longer than those used with cement. Because they depend on new bone growth for stability, cementless implants require a longer healing time than cemented replacements, in order to allow normal transmission of biomechanical forces across the joint. Cementless femoral components tend to be much larger at the top, with more of a wedge shape. This enables the strong surface (cortex) of the bone and the dense, hard spongy (cancellous) bone just below it to provide support. The acetabular component of a cementless THR also has a coated or textured surface to encourage bone growth into the surface. Depending on the surgeon and the technique used, the use of screws, spikes, pegs, or fins is common to help holding the implant in place until the new bone forms. These components are usually made from metal outer shell and a polyethylene liner.

The pelvis is prepared for a cementless acetabular component using a process similar to the one used in a cemented total hip replacement procedure. The contact between the component and bone is crucial to permit biological bone ingrowth, which is thought to enhance physiological loading and protect against proximal stress, shielding osteopenia of the femur.[16] Initially, it was hoped that cementless THR would erase the problem of bone resorption or stem loosening since there would be no complications linked to the use of cement. Three different kinds of stems are mainly used, according to their design: anatomic, tapered, and cylindrical. Although certain cementless stem designs have excellent long-term outcomes, cementless stems can still loosen if a strong bond between bone and stem is not achieved.

Patients with cementless stems may also experience a higher incidence of thigh pain, most commonly with the anatomically design of stem, according to the most published studies on anatomically shaped stems.[17] [18] Likewise, polyethylene wear, particulate debris, and the resulting osteolysis remain problems in both cemented and uncemented designs. Improvements in the wear characteristics of newer polyethylene, and research into newer bearing surfaces may help resolve some of these problems in the future.

At the end, cementless THR is most often recommended for younger, more active patients and patients with good bone quality where bone ingrowth into the components can be more easily achieved. Individuals with juvenile inflammatory arthritis may also be candidates, even though the disease may restrict their activities.

As cemented acetabular components have a tendency to loosen over time, the combination of a cementless acetabular component with a cemented femoral component is sometimes used. This type of prosthesis is the so-called hybrid type.

Arthritis of the hip affects mainly the articular surfaces of the joint and the subchondral bone. Hip resurfacing (HR) is a bone-conserving type of femoral implants which has recently emerged. HR has been performed for 15 years in both North America and Europe with favorable results.[19 20] In this procedure, the socket is replaced similar to a THR. The femur, however, is covered or "resurfaced" with a hemispherical component (Fig. 4)[21].

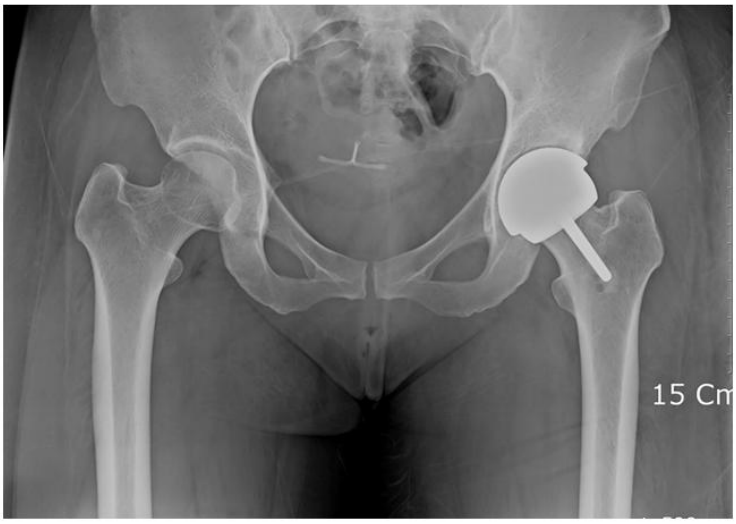

Figure 4. Hip resurfacing

This fits over the head of the femur and spares the bone of the femoral head and the femoral neck. It is fixed to the femur with cement around the femoral head and has a short stem that passes into the femoral neck.

The two surfaces join to create a metal-on-metal bearing surface area that has low-wear properties. Relative indications for HR surgery [22] include younger age, active occupational and lifestyle requirements, favorable bone anatomy and quality, normal weight, and male sex. It is too early to assess the long-term success of this procedure but it has to be kept in mind that resurfacing is not suitable for all hips.[23] The indications and limitations need to be recognized to reduce the number of technique-related failures, and improvements still have to be made regarding the resurfacing process, as well as the products of HR. Indeed, recently there have been cases of withdrawal of some prosthesis by the manufacturers because of component loosening, malalignment, infection, or fracture of the bone. One of the major Companies, DePuy Orthopaedics, Inc., a division of Johnson and Johnson, even recalled its ASR XL Acetabular metal-on-metal hip replacement system in August 2010, due to very high levels of revision rates and failures. [24] Additional complications from the hip replacement system may include increased metal ion levels in the blood, bone staining, necrosis, swelling, nerve damage, tissue and/or muscle damage.

The stability and fixation of implant are the essentials for durability. Research is currently focused on creation of an osteogenic stimulus to enhance bone ongrowth or heal bony defects.[25] [26] [27] One of the most promising field in development is working with nanotechnology to investigate the effectiveness of incorporating biologically active proteins onto implants to enhance their fixation to the bone.

The materials used for THR have greatly changed over the years. From the combination of a metal stem and ball with a plastic shell used by John Charnley, to the titanium alloy used by surgeons today, a lot of water has flowed under the bridge.

Nowadays, the stem portions of most hip implants are made of titanium- or cobalt/chromium-based alloys. The tapered titanium alloy cementless stem (Fig. 5)[28] has grown in popularity[29] and is becoming commonly used worldwide.

Achieving a press-fit via a single or dual tapered wedge with subsequent proximal osseo-integration of bone has proven successful in multiple long-term studies[30] of tapered titanium stems, with over 95% survival at 10 to 20 years.

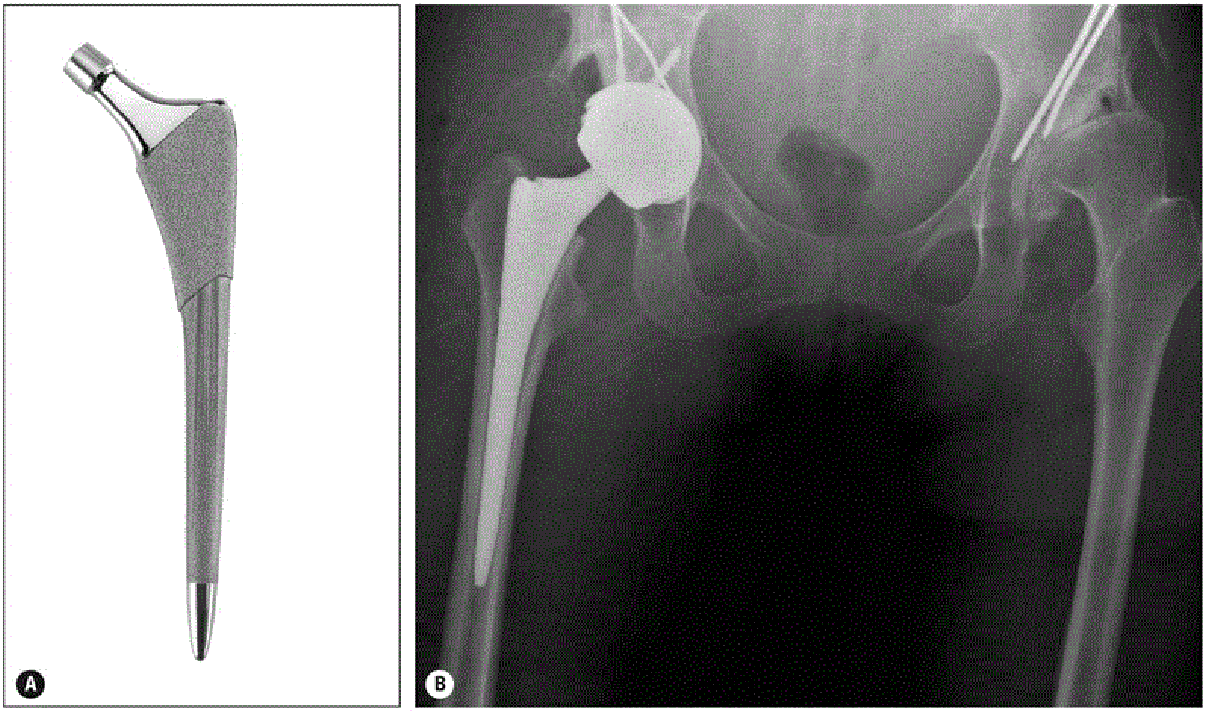

Figure 5. Cementless femoral component.

(A) Dual 3-degree tapered titanium component. The proximal portion of the stem has porous coating for bone ingrowth, while the middle of the stem is roughened by grit-blasting for bone ongrowth. (B) Postoperative X-ray showing a cementless tapered stem, cementless titanium acetabular component with screw fixation, and modular metal-on-metal bearing surface.

The ball portions are usually made from Cobalt/chromium-based alloys or ceramic materials (aluminum oxide or zirconium oxide). They are polished smooth to allow easy rotation within the prosthetic socket.

The acetabular socket can be made of metal, ceramic, ultra-high molecular-weight polyethylene, or a combination of polyethylene backed by metal. The long-term results of cementless titanium acetabular fixation have been favorable. At a minimum of 20 years, the implant survival for titanium hemispherical cups has recently been reported at over 95%.[31]

However, wear-related complications of the polyethylene liner inside and on the backside occur in approximately 20% of patients by 20 years, a problem that has become the focus of research in THR surgery.

Whatever the materials used to make the implant, they have to share several characteristics in common. They first have to be biocompatible, in order to avoid local or systemic rejection body response. They have to be resistant to corrosion, degradation, and wear, so they can retain their strength and shape for long time. Then, they all need to share properties that duplicate the structures they are intended to replace. For example, they are strong enough to withstand weight-bearing loads, flexible enough to bear stress without breaking, and able to move smoothly against each other as required. Finally, all these standards have to be at reasonable cost.

2.3. Surgical exposures

There are several types of surgical exposure used for THR. The two most common exposures are the anterolateral[32] and the posterolateral approaches to the hip.[33]

(Fig. 6)[34]. It is for this reason that the medial thigh muscles are not usually encountered during THR. All posterior approaches to the hip capsule require taking down the short external rotators while maintaining the abductors. In contrast, anterolateral and lateral approaches transect a portion of the gluteus medius and minimus in order to reach the hip capsule. With lateral approaches, care must be taken to ensure solid reattachment of the gluteus muscles in order to ensure the post-operative stability of the joint.

The anterolateral approach in total hip arthroplasty offers superb exposure that can be easily extended for complicated primary and revision surgery.

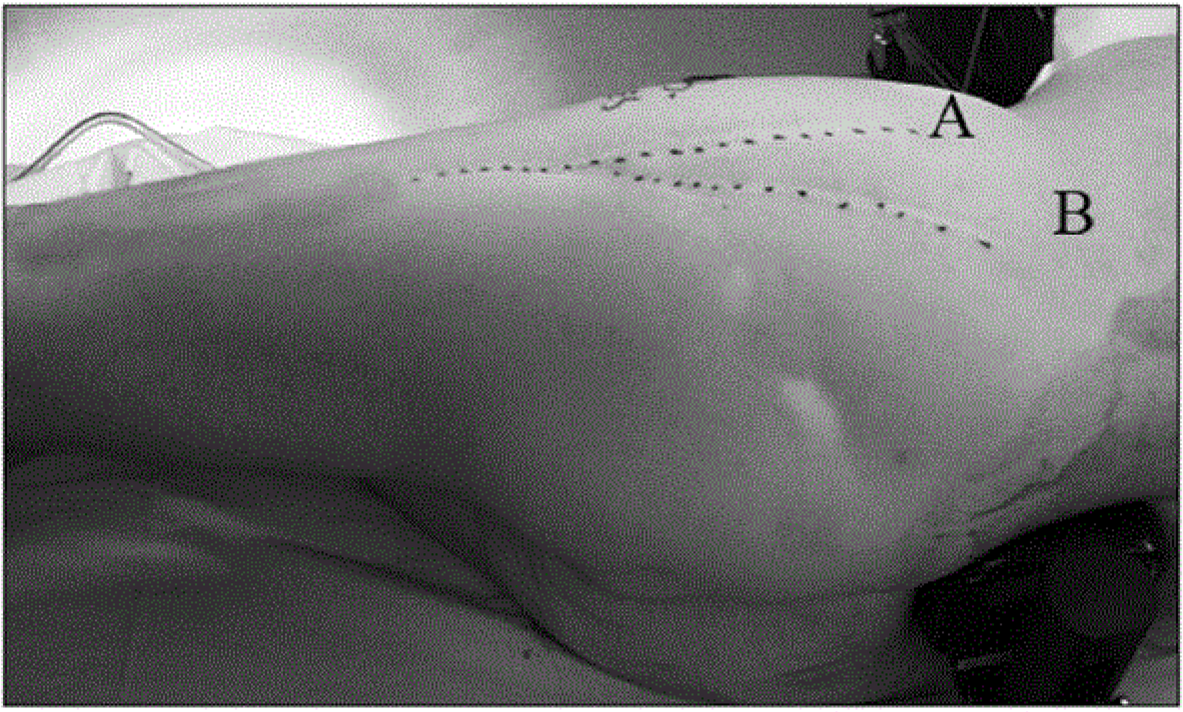

Figure 6. Common surgical exposures. (A) Anterolateral incision. (B) Posterolateral incision.

In addition, it can be adapted for small incision surgery. On one hand, the advantages of this approach include a significantly lower dislocation rate compared with other approaches while allowing for excellent acetabular visualization. But on the other hand, heterotopic ossification and limp are the two most common disadvantages.[35]

With the popularity of less invasive surgery, the postero-lateral exposure has again gained prominence. It is the most commonly used approach because it is technically simpler than other approaches and also because it does not interfere with the abductor mechanism of the hip. The disadvantages include a slightly higher risk of dislocation, although with experience this is minimized, the need for careful attention to component orientation in order to insert the implants in proper anteversion.

When minimally invasive surgery for THR is performed, it is most commonly performed using one of these two approaches.

However, in Canada between 2008 and 2009, the direct lateral approach (60%) and postero-lateral approach (36%) combined for over 95% of all surgical exposures[36], stripping away the anterolateral approach to the hip.

But others minimally invasive surgical approach options are available, including the two-incision approach[37] [38], the anterolateral (Watson-Jones) approach, and the direct anterior (Hueter) approach.[39]

A new mini-incision approach has been proposed by Wright et al.[40]. The main benefit of this approach is cosmesis. Other anticipated benefits were decreased blood loss, decreased operative time, and decreased hospital length.

Despite these techniques, other new techniques can be offered to the patient: the muscle-sparing technique, and the minimally invasive technique. The choice of the technique is operator-dependent, based upon its preferences and experience, and depending on the patient's morphology.

2.4. Minimally invasive surgery

While there may be a few short-term advantages to minimally invasive surgery, the early and mid-term results shown significant increased risks and surgical complications,[41] which have not been seen with using the other techniques.

Therefore, the enthusiasm for minimally invasive surgery has declined recently in favor of surgery performed safely through smaller incisions, and with the goal of achieving an ideal implant orientation and longevity.

2.5. Computer-assisted surgery (CAS)

This type of surgery for total hip replacement has gained popularity and is performed in many centers. It is too early to assess the long-term success of this procedure, but no advantages have been shown so far. The main disadvantage is increased orthopaedic rehabilitation time and increased cost. Overall, CAS has not been shown to be cost-effective to date.

3. LEVEL OF ACTIVITY

3.1. Physical Activity Level

The physical activity level (PAL) is a way to express a person's daily physical activity as a number, and is used to estimate a person's total energy expenditure (TEE).[42] In combination with the basal metabolic rate (BMR), it can be used to estimate the amount of food energy a person needs to consume in order to maintain a particular lifestyle. The physical activity level is defined for a non-pregnant, non-lactating adult as that person's total energy expenditure in a 24-hour period, divided by his or her BMR:

$$PAL = \frac{\mathrm{TEE/24h}}{\mathrm{BMR}}$$

3.2. Total energy expenditure (TEE)

The TEE is the energy spent, on average, in a 24-hour period by an individual or a group of individuals. It reflects the average amount of energy spent in a typical day. The TEE of free-living persons can be measured using the doubly labelled water technique (DLW). Others techniques are available, and among these, individually calibrated heart rate monitoring is commonly used. Using these methods, measurements of TEE over a 24-hour period include the metabolic response to food and the energy used for the tissue synthesis. For adults, this is equivalent to daily energy requirements. However, additional energy for deposition in growing tissues is needed to determine energy requirements in different situations like infancy, childhood, adolescence and pregnancy, and for the production and secretion of milk during lactation. Measurements of energy expenditure and energy requirement recommendations are expressed in units of energy (joules, J), according to the international system of units. Gender, age and body weight are the main determinants of total energy expenditure. Thus, energy requirements are presented separately for each gender and various age groups, and are expressed both as energy units per day and energy per kilogram of body weight. Most of the existing data on the TEE of adults are from studies in industrialized societies, although some investigations have been done in developing countries where many people have lifestyles associated with levels of physical activity that differ from those in industrialized countries (Coward, 1998).

3.3. Basal Metabolic Rate

BMR is the minimal rate of energy expenditure compatible with life. It is measured in the supine position under standard conditions of rest, fasting, immobility, thermoneutrality and mental relaxation. Depending on its use, the rate is usually expressed per minute, per hour or per 24 hours. BMR constitutes about 45 to 70 percent of TEE in adults.[43]

3.4. Categories of lifestyles

The average PAL of healthy, well-nourished adults is a major determinant of their total energy requirement. Energy requirements are highly dependent on habitual physical activity. This consultation classified the intensity of a population's habitual physical activity into three categories, based on the 1981 FAO/WHO/UNU expert consultation (WHO, 1985). The categories shown in Table 1 represent the different levels of activity associated with a population's lifestyle. These categories indicate the physical activity most often performed by most individuals in the population, over a period of time. The distributions of PAL for both men and women have a modal value

Table 1. Lifestyles in realtion to the intensity of habitual physical activity (PAL)

Category	PAL value
Sedentary or light activity lifestyle	1.40-1.69
Active or moderately active lifestyle	1.70-1.99
Vigorous or vigorously active lifestyle	2.00-2.40

at 1.6 (encompassing 1.55-1.65).[44] Western lifestyle is commonly referred to as 'sedentary', and the recommendation of FAO/WHO/UNU (1985) for light activity (1.55 × BMR) is frequently interpreted as 'sedentary'. A PAL of 1.55-1.65 appears to represent the average for the so-called sedentary lifestyle.

Today, not only the patients considered as light or moderately active patients are seeking for a complete restoration of their hip function but also highly active patients, including athletes expect to be able to go back into sports activity, including competition. These patients expect much more than pain relief; their goals of hip replacement now extend to function. Although most will have already self-restricted their activity before hip replacement[45] , some make seek a return to some sports that are unrealistic or unsafe to practice. It is the surgeon’s responsibility to preoperatively guide these patients to distinguish between reasonable and unreasonable athletic expectations.

4. ACTIVITY AFTER HIP ARTHROPLASTY

4.1. Benefits

The benefits brought by the practice of physical activity following total joint arthroplasty (TJA) are undeniable. Aside to the psychological satisfaction that patients derive from athletic activity, there are the benefits of improved muscle strength, coordina-tion, balance, endurance, and proprioception, all of which contribute to better body control and may prevent injury from simple falls and other minor trauma. Furthermore, studies have shown that cardiovascular fitness is positively affected by exercise after both hip arthroplasty, with significant improvements shown for exercise duration, maximum workload, and peak oxygen consumption 2 years postoperatively.[46 47]

Studies also support the conclusion that TJA may allow people to return to high levels of activity and recreational exercise. Moreover, individuals who were relatively sedentary prior to joint arthroplasty sometimes begin to participate in activity after a joint replacement.[48]

4.2. Classification of sport activities

A study performed by Visuri and Honkanen [49] showed that after total hip replacement, patients significantly increased their participation in low-impact activities, such as exercise walking, cycling, swimming, and cross-country skiing.

To date, there are no prospective controlled studies on longevity of Total Hip Arthroplasty (THA) implants in patients practicing sport after the operation. Nonetheless, a few validated guidelines exist for a return to sports after the operation. Current recommendations are based on a consensus of opinion and practice patterns. Surgeons at the Mayo Clinic in 1995 listed some activities as recommended, intermediate, and not recommended based on a similar survey[50] . In 1999, Healy et al[51] surveyed 54 members of the Hip Society (HS) concerning the re-

Table 2. Classification of Sports Based on Recommended Activity after THA.

	Allow (%)			Allow With Experience (%)			Not Allowed (%)			Undecided (%)		
Sports	AAHKS	HS	Total	AAHKS	HS	Total	AAHKS	HS	Total	AAHKS	HS	Total
Golf	**99**	**100**	**99**	0	0	0	0	0	0	0	0	0
Swimming	**99**	**100**	**99**	1	0	1	1	0	1	0	0	0
Singles tennis	15	15	16	29	30	28	**52**	**49**	**52**	4	6	4
Doubles tennis	**63**	**62**	**64**	30	30	29	6	6	6	1	2	1
Racquetball/squash	11	8	11	28	21	27	**60**	**66**	**60**	2	6	2
Stairclimber	**72**	**62**	**72**	10	17	10	14	17	14	3	4	3
Walking	**98**	**100**	**98**	1	0	1	0	0	0	0	0	0
Speedwalking	**81**	**87**	**81**	8	4	8	9	6	9	2	4	2
Jogging	6	2	6	5	4	5	**88**	**92**	**87**	2	2	2
Hiking	**79**	**79**	**79**	18	14	18	3	2	3	1	2	1
Downhill skiing	21	28	21	**56**	**62**	**56**	22	9	22	0	0	0
Snowboarding	11	13	11	28	**42**	28	**55**	36	**55**	7	9	6
Cross-country skiing	**55**	**64**	**56**	38	30	37	6	6	5	1	0	1
Stationary skiing	**87**	**91**	**87**	11	9	11	2	0	1	1	0	0
Bowling	**90**	**94**	**90**	8	6	8	1	0	1	1	0	1
Contact sports	2	0	2	3	6	2	**93**	**91**	**93**	2	4	2
Baseball/softball	13	15	13	27	26	27	**57**	**57**	**57**	3	2	3
Weight machines	**61**	**47**	**60**	33	40	33	5	13	5	2	0	1
Weightlifting	**46**	38	**46**	34	**42**	33	18	19	19	2	2	2
Ice skating/rollerblading	34	40	35	**43**	**42**	**43**	22	19	21	2	0	2
Treadmill	**87**	**89**	**87**	8	6	8	4	6	4	2	0	1
Road cycling	**80**	**75**	**80**	19	23	19	1	2	1	0	0	0
Stationary bicycle	**95**	**92**	**95**	5	8	5	0	0	0	0	0	0
Elliptical machine	**93**	**91**	**92**	5	8	5	1	0	1	1	2	1
Low-impact aerobics	**86**	**87**	**86**	9	8	9	5	4	4	0	2	0
High-impact aerobics	6	2	6	7	11	7	**84**	**85**	**84**	3	2	3
Pilates	**58**	**68**	**58**	24	19	24	9	11	10	9	2	9
Rowing	**64**	**64**	**64**	21	28	21	13	6	13	2	2	2
Dancing	**93**	**100**	**94**	6	0	6	0	0	0	0	0	0
Martial arts	9	11	9	39	34	38	**48**	**51**	**49**	4	4	4

HS: Hip society. AAHKS: American Association of Hip and Knee Surgeons.

-turn to sporting activities and classified the results into 4 different categories (Table 2): allow, allow with experience, not allowed, and undecided. The Hip Society placed the following sports into the allowed category: stationary cycling, croquet, ballroom dancing, golf, horseshoes, shooting, shuffleboard, swimming, doubles tennis, and walking.

Sports that were allowed with experience were low-impact aerobics, road cycling, bowling, canoeing, hiking, horseback riding, and cross-country skiing. No conclusion was made regarding participation in jazz dancing, fencing, ice skating, roller skating or in-line skating, rowing, speed walking, downhill skiing, stationary skiing, weight lifting, and weight machines.

Table 3. Classification of Sports Based on Level of Impact

Low Impact	Potentially Low Impact	Intermediate Impact	High Impact
Stationary cycling	Bowling	Free weights	Baseball, softball
Calisthenics	Fencing	Hiking	Basketball
Golf	Rowing	Horseback riding	Volleyball
Stationary skiing	Isokinetic weights	Ice skating	American football
Swimming	Sailing	Rock climbing	Racquetball, handball
Walking	Speed walking	Low-impact aerobics	Jogging, running
Ballroom dancing	Cross-country skiing	Tennis	Lacrosse
Water aerobics	Table tennis	In-line skating	Soccer
	Jazz and ballet	Downhill skiing	Water-skiing
	Bicycling		Karate

In an article published in 2005, Clifford and Mallon[52] provided their own guidelines, based on the available literature, and on the athletic and exercise participation after THR (Table 3). “Low-impact“ activities are encouraged for all patients, as they help improve general health and cardiovascular fitness. These activities include swimming, walking, golf, stationary bike, treadmill, and elliptical machines, and they focus on conditioning and flexibility, rather than heavy loading for strengthening. Activities classified as “potentially low impact,“ such as bicycling, speed walking, cross-country skiing, dancing, Pilates, and rowing, require patients to have good balance and proprioception, and patients participating in these activities should be monitored by their surgeon on a regular basis in which emphasis should be on a high number of repetitions with minimal resistance. Activities classified as “intermediate impact" include tennis, hiking, downhill skiing and snowboarding, weightlifting, ice skating and rollerblading, and low-impact aerobics. These may be allowed for a select group of patients. Excellent physical condition and previous experience with these sports are required to minimize risk of injury and accelerated implant wear. Orthotics and braces may be of some use in helping reduce impact and torsional loads on replaced joints.[53]

Finally, most THR patients should be strongly discouraged from participation in very high-impact athletics, especially those with high risk of contact. This class includes such sports as martial arts, rock climbing, racquetball, running, high-impact aerobics, and most ball sports. There is likely a higher risk of injury and need for revision with these activities. However, with the arrival of newer implants and the inclusion of younger patients in the arthroplasty population, it is very likely that more and more patients with THR will be participating in these sports. Patients should be counseled appropriately, and on an individual level, as the effect of high-impact athletic participation remains to be determined.

With the support of the HS and the American Association of Hip and Knee Surgeons (AAHKS), a web-based survey (Survey Monkey, surveymonkey.com , Portland , OR) was sent to the 93 active members of the HS and the 645 active members of AAHKS with e-mail addresses on file. There were 60 surgeons who were members of both groups and were included in the results for both the HS and AAHKS. The survey listed 37 different sports brought together into 30 different groups and the surgeons were asked to classify their recommendations for a standard (metalon-polyethylene) THA into 1 of 4 categories: allow, allow with experience, not allowed, or undecided.

Participants were also queried for their recommendation on when they allow patients to return to physical activities.

Table 4. Consensus Guidelines for Return to Activities by the Members of the HS and AAHKS. Italic type denotes classification change from a previous study by Healy [12]: 1, change from undecided; 2, change from not allowed; 3, change from allowed with experience; 4, change from allowed. Underline denotes activity not previously described.

Allow	Allow With Experience	Not Allowed	Undecided
Golf	*Downhill skiing* [1]	Racquetball/squash	Martial arts
Swimming	Cross-country skiing	Jogging	*Singles tennis* [2]
Doubles Tennis	*Weightlifting* [1]	Contact sports (football, basketball, soccer)	
Stairclimber	*Ice Skating/rollerblading* [1]	High-impact aerobics	
Walking	Pilates	Baseball/softball	
Speed walking [1]		Snowboarding	
Hiking [3]			
Stationary skiing [1]			
Bowling [3]			
Treadmill			
Road cycling [3]			
Stationary bicycling			
Elliptical			
Low-impact aerobics [3]			
Rowing [1]			
Dancing (ballroom, jazz, square) [1]			
Weight machines			

The results are that ninety-two (93%) of the 98 active members of the HS and 522 (72%) of the 727 members of AAHKS responded (72% response rate for the combined societies). Five and 14 members of the HS and AAHKS responded but were excluded because they did not perform THA (3 and 4) or refused to participate (2 and 10), respectively. The distributions of responses to activity recommendations by all surgeons are listed in Table 2. Consensus guidelines on return to sports after THA for a standard THA (metal on polyethylene) by members of the HS and AAHKS are listed in Table 4. There were no significant differences between these 2 societies with only minor variations in their overall recommendations. The activities that differed between the 2 societies were stairclimber, doubles tennis, weight machines, snowboarding, and rowing. All of these activities were allowed with experience by the members of the HS and were allowed regardless of experience by the members of

Table 5. Time Interval Recommended Before Allowing Return to Activities After THA

Time Interval (mo)	AAHKS (%)	HS (%)	Combined (%)	*P*
0-1	0.8	0	0.6	NS
1-3	32.5	24	32	NS
3-6	60.4	71	59	.001
6-12	5.1	2	5	NS
>1 year	0.6	2	0.6	NS

NS indicates not significant.

AAHKS, except for snowboarding, which was not allowed and undecided, respectively. There was no significant difference in the percentage of responses for these activities, and the variation in overall recommendation is likely a function of the greater number of members and responses from AAHKS members.

Thirty-three percent of AAHKS members allowed the patients to return to sports within the first 3 months postoperatively compared with 24% from the HS. Although this was a trend toward allowing an earlier return to sports, this value was not significant (P = .08). Seventy-one percent of the HS members recommended a return to sports at 3 to 6 months, whereas only 58.4% of AAHKS members recommended this time interval for return to sporting activities (P = .001).

By combining the results of the 2 societies, it appears that waiting 3 to 6 months after a THA is the current recommended waiting time for return to physical activities (Table 5).

5. REHABILITATION AFTER THR

5.1. Benefits

It has been suggested that more intensive physical post-operative therapy may prove beneficial to patients hoping to resume athletic activities[54]. More precisely, regimens aimed at improved hip abductor strength may improve the ability to return to the practice of sports. Moreover, it has been suggested that prolonged use of ambulatory assistive devices could actually improve functional outcomes in active patients[55]. These new results are challenging the previous beliefs where the progression to full weight bearing as rapidly as possible was thought to be best for outcomes relating to patient activity. In addition, in younger and more active patients, allowing for a slower return to full weight bearing may prevent patients from attempting higher impact activities too early in the post-operative period, and therefore leading to a better long-term functionality of the implant.

5.2. Total Hip Replacement Exercise Protocol

A number of rehabilitation exercise protocols are used by various institutions for total hip replacement. Nonetheless, the functional goals of these protocols are the same.[56]

The following protocol is based on Abraham T Rasul Jr studies, “Total Hip Replacement Exercise Protocol” [57]

5.2.1. Preoperatively (1-2 weeks prior to surgery)

The protocol includes educating the patient about the surgical process and its outcomes, instructing him or her on a postoperative exercise program, and assessing the patient's home environment. It also involves educating the patient on total hip precautions, as follows:

- No hip flexion beyond 90°
- No crossing of the legs (hip adduction beyond neutral)
- No hip internal rotation past neutral

The above precautions apply to the posterior surgical approach to the hip. With the anterior hip approach, the patient can cross his or her legs and internally rotate the hip, although positions that involve extreme hip extension and external rotation will dislocate the hip.

5.2.2. First-day postoperative protocol

It includes the following:

- Initiation of bedside exercises - Such as ankle pumps, quadriceps sets, and gluteal sets
- Review of hip precautions and weight-bearing status
- Initiation of bed mobility and transfer training - Bed to/from chair

5.2.3. Second-day postoperative protocol

It includes the following:

- Initiation of gait training with the use of assistive devices, such as crutches and a walker
- Continuation of functional transfer training

5.2.4. Postoperative protocol on discharge to the rehabilitation unit (or days 3 to 5)

It includes the following:

- Progression of ROM and strengthening exercises to the patient's tolerance
- Progression of ambulation on level surfaces and stairs (if applicable) with the least restrictive device[58]
- Progression of ADL training

Rahmann et al found that aquatic physiotherapy can promote early recovery of hip strength in patients who have undergone hip or knee arthroplasty.[59]

In a randomized, controlled trial that compared the results of supplementary inpatient physiotherapies—aquatic physiotherapy, nonspecific water exercise, and additional ward physiotherapy—in 65 patients, a specific inpatient aquatic physiotherapy program, begun on day 4, was associated with significantly greater hip abductor strength by day 14.

5.2.5. Postoperative protocol from day 5 to 4 weeks

It includes the following:

- Strengthening exercises - For example, seated leg extensions, side-lying/standing hip abduction, standing hip extension and hip abduction, knee bends, bridging
- Stretching exercises to increase the flexibility of hip muscles
- Progression of ambulation distance
- Progression of independence with ADL

A study by Husby et al indicated that maximal strength training, starting 1 week postoperatively, is a valuable addition to conventional rehabilitation after THR.[60] In a randomized, controlled study in 24 patients, one group performed maximal strength training in leg press and abduction only with the operated leg, 5 times a week for 4 weeks.

Compared with patients who received only conventional rehabilitation, the patients who engaged in strength training demonstrated increased 1-repetition maximum leg press strength, an increased rate of force development, and a tendency toward improved work efficiency. No differences in gait patterns were noted between the groups.

In order to prevent postoperative leg-length discrepancy, leg lengths are measured during the preoperative phase. Measurement is performed radiologically and clinically by measuring the actual leg lengths. During the operative process, however, leg lengths can change, depending on how the prosthesis is fixed or stabilized or on how much bone needs to be removed, among other surgical considerations.

Therefore, it is important in the postoperative phase to correct any leg-length discrepancy by using appropriate orthoses or heel lifts since the correction of discrepancies has a direct impact on the patient's gait pattern, as well as on the development of low back pain.[61]

6. CONCLUSION

Evaluating the practice of sports following THR is difficult because of the lack of long-term, prospective studies, the variability in surgeon's preferences, surgical techniques, and the patient's abilities and interests. Nevertheless, the scientific societies have made some recommendations regarding the type of sports being practiced. After the relief of pain and recovery of walking, the practice of sports and physical activities is the third patient's expectation after THR. This represents now a reality for orthopedic surgeons who must respond pragmatically to these new expectations by explaining the benefits and risks of participating in such activities. These risks include instability, per prosthetic fractures , implants loosening, as well as premature wear of the articular surfaces. The global benefits brought by the operation have to take into consideration the cardiovascular benefits, the mental and physical well -being and psychologic aspects as well. All of them contribute to the degree of patient satisfaction after THR, and are especially important for the patients who are motivated to resume sports activities after prosthesis. The most practiced physical activities, or the one most frequently authorized by surgeons according to the most recent studies remain walking, biking, swimming, gardening, jogging, dancing and golf. Other activities, such as tennis or skiing, require prior acquisition of a good technical level before replacement or setting up a real specific rehabilitation program before and after the introduction of the prosthesis, including especially stretching and strengthening of the hip muscles. In conclusion, the surveys made so far should be considered as guidelines for the practice of sport after hip arthroplasty, but definitive recommendations have to be refined by individual surgeons, based on each patient's expectations and goals.

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8. REFERENCES

[1] Ian D Learmonth, Claire Young, Cecil Rorabeck. The operation of the century: total hip replacement. Lancet 2007;370:1508-19

[2] R. Stephen, J. Burnett. Total hip arthroplasty : Techniques and results. BCMJ, Vol. 52, No. 9, November 2010, page(s) 455-464 Articles

[3] http://www.exac.com/patients-caregivers/joint-replacement-surgery/hip-replacement/components-hip-replacement

[4] Robert Pivec, Aaron J Johnson, Simon C Mears, Michael A Mont. Hip arthroplasty. The Lancet, Volume 380, Issue 9855, 17–23 November 2012, Pages 1768–177

[5] Gluck T. Referat über die durch das moderne chirurgische Experiment gewonnenen positiven Resultate, betreffend die Naht und den Ersatz von Defecten höherer Gewebe, sowie über die Verwethung resorbirbarer und lebendiger Tampons in der Chirurgie. Arch klin chir. 1891;41:187–239.

[6] Charnley J.Anchorage of the femoral head prosthesis to the shaft of the femur. J Bone Joint Surgr Br 1960; 42B: 28-30

[7] Majkowski RS, Miles AW, Bannister GC, Perkins J, Taylor GJ. Bone surface preparation in cemented joint replacement. J Bone Joint Surg Br 1993; 75: 459-63

[8] Breusch SJ, Norman TL, Schneider U, Reitzel T, Blaha JD, Lukoschek M: Lavage technique in total hip arthroplasty:jet lavage produces better cement penetration than syringe lavage in the proximal femur. J Arthroplasty 2000; 15: 921-27

[9] Herberts P, Malchau H. Long-term registration has improved the quality of hip replacement: a review of the Swedish THR Register comparing 160,000 cases. Acta Orthop Scand 2000; 71: 111-21

[10] Mulroy RD Jr, Harris WH. The effect of improved cementing techniques on component loosening in total hip replacement. An 11-year radiographic review.

[11]http://orthoinfo.aaos.org/topic.cfm?topic=A00355#Cemented%20Total%20Hip%20Replacement

[12] http://www.nytimes.com/interactive/2011/12/28/business/Sources-of-Debris-in-Artificial-Hips.html?_r=0

[13] Maloney WJ, Jasty M, Rosenberg A, Harris WH. Bone lysis in well-fixed cemented femoral components. J Bone Joint Surg Br. 1990 Nov;72(6):966-70.

[14] Jasty MJ, Floyd WE 3rd, Schiller AL, Goldring SR, Harris WH. Localized osteolysis in stable, non-septic total hip replacement. J Bone Joint Surg Am. 1986 Jul;68(6):912-9

[15] Jones LC, Hungerford DS. Cement disease. Clin Orthop Relat Res. 1987 Dec;(225):192-206

[16] Keaveny TM, Bartel DL. Mechanical consequences of bone ingrowth in a hip prosthesis inserted without cement. J Bone Joint Surg Am. 1995 Jun;77(6):911-23

[17] McAuley JP, Culpepper WJ, Engh CA. Total hip arthroplasty. Concerns with extensively porous coated femoral components. Clin Orthop Relat Res. 1998 Oct;(355):182-8

[18] Campbell AC, Rorabeck CH, Bourne RB, Chess D, Nott L. Thigh pain after cementless hip arthroplasty: annoyance or ill omen. J Bone Joint Surg Br. 1992 Jan;74(1):63-6

[19] Treacy RB, McBryde CW, Pynsent PB. Birmingham hip resurfacing arthroplasty. A minimum follow-up of five years. J Bone Joint Surg Br 2005;87:167-170

[20] Amstutz HC, Le Duff MJ. Eleven years of experience with metal-on-metal hybrid hip resurfacing: A review of 1000 conserve plus. J Arthroplasty 2008;23(suppl):36-43

[21] http://www.lct.co.kr/en/specialty/hipresurfacing.php

[22] Della Valle CJ, Nunley RM, Barrack RL. When is the right time to resurface? Orthopedics 2008;31(suppl)

---

[23] Eastaugh-Waring SJ, Seenath S, Learmonth DS, Learmonth ID. The practical limitations of resurfacing hip arthroplasty. J Arthroplasty. 2006 Jan;21(1):18-22

[24] http://en.wikipedia.org/wiki/2010_DePuy_Hip_Recall

[25] Bragdon CR, Doherty AM, Rubash HE, Jasty M, Li XJ, Seeherman H, Harris WH. The efficacy of BMP-2 to induce bone ingrowth in a total hip replacement model. Clin Orthop Relat Res. 2003 Dec;(417):50-61

[26] Bragdon CR, Jasty M, Greene M, Rubash HE, Harris WH. Biologic fixation of total hip implants. Insights gained from a series of canine studies. J Bone Joint Surg Am. 2004;86-A Suppl 2:105-17

[27] Jasty M, Rubash HE, Paiement GD, Bragdon CR, Parr J, Harris WH. Porous-coated uncemented components in experimental total hip arthroplasty in dogs. Effect of plasma-sprayed calcium phosphate coatings on bone ingrowth. Clin Orthop Relat Res. 1992 Jul;(280):300-9

[28] http://www.bcmj.org/sites/default/files/BCMJ_52Vol9_hip_arthroplasty_fig4.gif

[29] Danesh-Clough T, Bourne RB, Rorabeck CH, et al. The mid-term results of a dual offset uncemented stem for total hip arthroplasty. J Arthroplasty, 2007;22:195-203

[30] Lombardi AV Jr, Berend KR, Mallory TH, et al. Survivorship of 2000 tapered titanium porous plasma-sprayed femoral components. Clin Orthop Relat Res 2009;467:146-154

[31] Della Valle CJ, Mesko NW, Quigley L, et al. Primary total hip arthroplasty with a porous-coated acetabular component. A concise follow-up, at a minimum of twenty years, of previous reports. J Bone Joint Surg Am 2009;91:1130-1135

[32] Mulliken BD, Rorabeck CH, Bourne RB, et al. A modified direct lateral approach in total hip arthroplasty: A comprehensive review. J Arthroplasty 1998;13:737-747

[33] Kwon MS, Kuskowski M, Mulhall KJ, et al. Does surgical approach affect total hip arthroplasty dislocation rates? Clin Orthop Relat Res 2006;447:34-38

[34] R. Stephen J. Burnett, MD, FRCSC, Dipl ABOS, BCMJ, Vol. 52, No. 9, November 2010, page(s) 455-464 Articles

[35] Matthew S. Austin, William J. Hozack. *Seminars in Arthroplasty*, *Volume 15, Issue 2*, *April 2004*, *Pages 79-82*

[36] Canadian Institute for Health Information. Hip and knee replacements in Canada—Canadian Joint Replacement Registry (CJRR) 2008–2009 annual report.

[37] Bal BS, Haltom D, Aleto T, et al. Early complications of primary total hip replacement performed with a two-incision minimally invasive technique. Surgical technique. J Bone Joint Surg Am 2006;88:(suppl):221-233

[38] Berger RA, Duwelius PJ. The two-incision minimally invasive total hip arthroplasty: Technique and results. Orthop Clin North Am 2004;35:163-172

[39] Seng BE, Berend KR, Ajluni AF, et al. Anterior-supine minimally invasive total hip arthroplasty: Defining the learning curve. Orthop Clin North Am 2009;40:343-350.

[40] Wright, J. M., Crockett, H. C., Sculco, T. P. Mini-incision for total hip arthroplasty. Orthopedics (Special Edition) 7(2), 2001

[41] Bal BS, Haltom D, Aleto T, et al. Early complications of primary total hip replacement performed with a two incision minimally invasive technique. Surgical technique. J Bone Joint Surg Am 2006;88:(suppl):221-233

[42] "Total energy expenditure (TEE) and physical activity levels (PAL) in adults: doubly-labelled water data". Energy and Protein requirements, Proceedings of an IDECG workshop. United Nations University. 1994-11-04. Retrieved 2009-10-15

[43] http://www.fao.org/docrep/007/y5686e/y5686e07.htm

[44] http://archive.unu.edu/unupress/food2/UID01E/UID01E08.HTM

[45] Kilgus DJ, Dorey FJ, Finerman GA, et al. Patient activity, sports participation, and impact loading on the durability of cemented total hip replacements. Clin Orthop Relat Res 1991;269:25–31

[46] Ries MD, Philbin EF, Groff GD, et al. Improvement in cardiovascular fitness after total knee arthroplasty. J Bone Joint Surg Am. 1996 Nov;78(11):1696-701.

[47] Ries MD, Philbin EF, Groff GD, et al. Effect of total hip arthroplasty on cardiovascular fitness. J Arthroplasty. 1997 Jan;12(1):84-90.

[48] Visuri T, Honkanen R. Total hip replacement: its influence on spontaneous recreation exercise habits. Arch Phys Med Rehabil. 1980 Jul;61(7):325-8.

[49] Diduch DR, Insall JN, Scott WN, et al. Total knee replacement in young, active patients. Long-term follow-up and functional outcome. J Bone Joint Surg Am. 1997 Apr;79(4):575-82.

[50] McGrory BJ, Stuart MJ, Sim FH. Participation in sports after hip and knee arthroplasty: review of literature and survey of surgeon preferences. Mayo Clin Proc 1995;70(4):342–8

[51] Healy WL, Iorio R, Lemos MJ. Athletic activity after joint replacement. Am J Sports Med 2001;29:377

---

[52] Clifford PE, Mallon WJ. Sports after total joint replacement. Clin Sports Med. 2005 Jan;24(1):175-86

[53] Clifford PE, Mallon WJ. Sports after total joint replacement. Clin Sports Med. 2005 Jan;24(1):175-86.

[54] Jacobs CA, Christensen CP, Berend ME. Sport activity after total hip arthroplasty: Changes in surgical technique, implant design, and rehabilitation. J Sport Rehabil 2009; 18(1): 47-59.

[55] Perrin T, Dorr LD, Perry J, Gronley J, Hull DB. Functional evaluation of total hip arthroplasty with five- to ten-year follow-up evaluation. Clin Orthop Relat Res 1985; (195): 252-60.

[56] Schneider M, Kawahara I, Ballantyne G, et al. Predictive factors influencing fast track rehabilitation following primary total hip and knee arthroplasty. *Arch Orthop Trauma Surg*. Feb 7 2009

[57] Abraham T Rasul Jr, Wright J, Salcido R, Slipman W C. Total Joint Replacement Rehabilitation. Mar 19, 2014

[58] Andriacchi TP, Andersson GB, Fermier RW, et al. A study of lower-limb mechanics during stair-climbing. *J Bone Joint Surg Am*. Jul 1980;62(5):749-57.

[59] [Best Evidence] Rahmann AE, Brauer SG, Nitz JC. A specific inpatient aquatic physiotherapy program improves strength after total hip or knee replacement surgery: a randomized controlled trial. *Arch Phys Med Rehabil*. May 2009;90(5):745-55.

[60] [Best Evidence] Husby VS, Helgerud J, Bjorgen S, et al. Early maximal strength training is an efficient treatment for patients operated with total hip arthroplasty. *Arch Phys Med Rehabil*. Oct 2009;90(10):1658-67.

[61] Abraham T Rasul Jr, Wright J, Salcido R, Slipman W C. Total Joint Replacement Rehabilitation. Mar 19, 2014