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Review

The effect of hip arthroplasty on gait. A review

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Abstract

Hip arthroplasty is one of the most successful orthopaedic procedures because it offers pain relief and good postoperative function. However, some patients complain of gait changes and a marked reduction in their walking pace. These changes may be due to altered offset, leg length discrepancy and hardware positioning and may persist even a year after their operation . This review aims to assess hip replacement-related gait alterations as well as their causes and their clinical impact. Gait analysis after THR can provide important information that could improve our decision making in our clinical practice.

Keywords

Hip replacement; gait changes; leg length discrepancy; global offset; femoral stem anteversion

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Introduction

Total hip replacement (THR) is considered one of the most successful orthopaedic procedures. This is because it offers a satisfactory surgical outcome along with considerable pain alleviation. The majority of patients who elect to undergo THR present end-stage osteoarthritis (OA). The latter experience significant loss of their functionality and are incapable of walking and performing their daily activities. Moreover, they often complain of gait changes and a marked reduction in their walking pace.

Regardless, 10–20 % of THR patients continue having issues regarding their working capacity, gait pattern, overall function and quality of life postoperatively.[1,2] Despite being relatively rare, gait asymmetry and noticeable limping may persist.[3,4] With pain and impaired function being the main indications for surgery, THR is considered unsuccessful in such cases. This review aims to assess THR-related gait alterations as well as their causes and their clinical impact.

Gait analysis

The variables investigated in gait analysis are spatiotemporal, kinematic and kinetic (Figure 1). Spatiotemporal parameters are distance-related. They include step and stride length as well as time-related parameters such as walking speed and stride time. Kinematic gait variables investigate the angular motion of the body, limbs, and joints during movement. Kinetic gait variables explore the forces resulting from movement.

Most studies investigating gait changes after THR compared their results with those of healthy subjects. Reduced walking speeds, step and stride lengths and gait deviation are commonly identified. Furthermore, coronal and sagittal range of motion deficits have also been reported.[5,6] In addition to these findings, several studies refer to poor trunk control in the mediolateral direction.[7,8] The former could be attributed to a posture consisting of lateral bending toward the affected side. The reduction in the volume of gluteus minimus has been identified as a factor involved in this gait deviation and contributes to higher hip joint loads up to 3 months after the intervention.[9] Likewise, the atrophy of this muscle has been used as a predictor of the weakness of the gluteus medius, which is the dominant hip abductor.[10] As a result, the mechanical demand on weaker hip abductor muscles is reduced further while the balance in the frontal plane is facilitated. However, the load asymmetry between the two limbs increases the number of stresses put on the contralateral hip joint and could potentially lead to OA, or increase the risk of falls.

Bahl et al. assessed changes in gait biomechanics after THR. They compared the postoperative status of THR patients to healthy controls up to 2 years after surgery. This systematic review illustrated moderate to large pre to post-operative changes from 6 weeks to 12 months in spatiotemporal and kinematic parameters. Functional and clinical improvements were apparent as early as the sixth postoperative week. Nevertheless, greater improvements were documented in 6 months, with the best results appearing approximately one year after the surgery. Although some parameters turned near normal after THR, residual deficits in walking speed, stride length and sagittal plane hip ROM existed at 12 months postoperatively. Step width was wider compared to healthy individuals at 6 weeks and 3 months. The kinematic data revealed increases in sagittal and transverse plane hip ROM at 6 weeks and up to 12 months whilst coronal plane hip abduction/adduction revealed no significant change.[11]

Naili et al. indicated improvement in performance-based and patient-reported functions a year following THR, even though greater improvement was documented in patient-reported functions. These findings suggest that objectively measured improvements in performance-based function and gait are not in line with patient-reported functional improvements. Therefore, they highlighted the importance of using both subjective and objective methods for evaluating function following THR.[12]

Kaufmann et al. investigated the functional outcome of THR. Apart from comparing OA patients with normal controls they also documented the pre and postoperative outcomes in OA patients. They indicated that walking speed and cadence improved significantly in postoperative assessments of patients with hip OA. Stride duration decreased

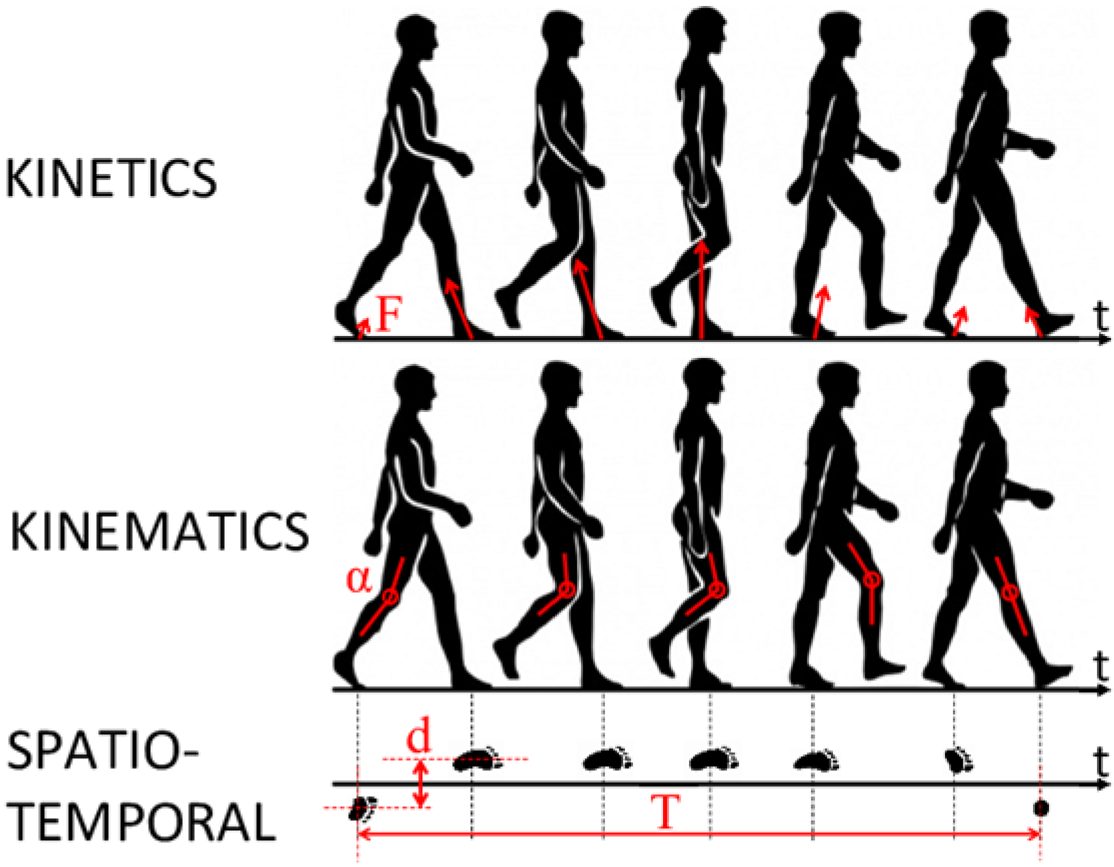

Figure 1. Kinetic gait variables explore the forces resulting from movement. Kinematic gait variables investigate the angular motion of the body, limbs, and joints during movement. Spatiotemporal parameters are distance-related. They include step and stride length as well as time-related parameters such as walking speed and stride time.

after surgery whilst there was no significant difference in stride length postoperatively. Moreover, hip flexion angles during stance and swing and knee flexion angles during loading response and swing were significantly larger postoperatively. Conversely, knee flexion angles during terminal stance were significantly smaller postoperatively whereas THR had no impact on ankle kinematics. When compared to healthy controls, kinematic parameters improved and did not differ from asymptomatic controls 1 year postoperatively. In contrast, spatiotemporal parameters improved postoperatively but remained inferior to asymptomatic controls.[13]

Foucher et al. suggested that the preoperative gait status may be related to the postoperative outcome.[14] The same primary author also demonstrated that preoperative gait, clinical factors and patient characteristics predicted up to 33% of the variability in postoperative gait.[15] They also proposed that intense preoperative and postoperative rehabilitation could be helpful for some THR patients.[14] , Indeed, some studies confirmed improvements in post-operative walking speed and stride length after a peri-operative exercise programme, in comparison with conventional care regimens.[16]

To achieve personalization of the prosthesis and optimal therapeutic effect after THR, surgeons put great effort into selecting the best combination of implant components. Choosing adequate implants and meticulous hardware positioning during total hip replacement is important for improving the outcome and maximizing the results of the surgery. Following a carefully tailored surgical plan may also facilitate restoring limb function and hip biome-

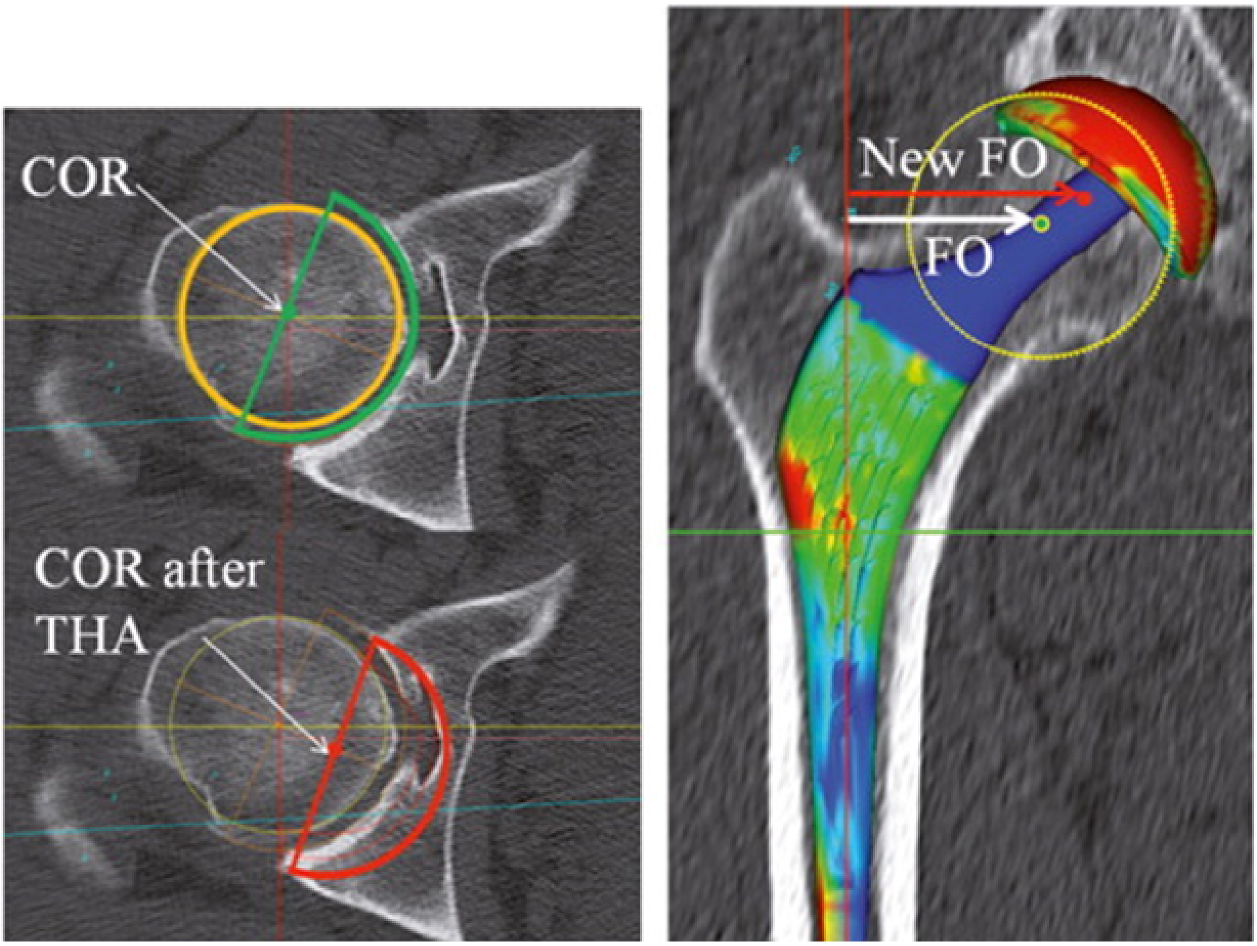

Figure 2. Medialization during acetabular preparation reduces the GO. To restore the latter, a stem with a higher offset may be required. The compensatory increase of femoral offset (FO) is indicated because it reduces the risk of dislocation, decreases polyethylene wear, lowers the risk of edge loading and restores soft tissue tension.

chanics, rehabilitation and help lower socioeconomic factors associated with total joint replacement.

The number of studies investigating the effect of the implant head size on the gait pattern after total hip replacement is limited.[17] Large femoral head implants have been linked to a higher risk of taper corrosion and groin pain due to impingement of the head implant on the psoas muscle. Since the femoral head size has a proven impact on the range of motion, it is highly probable that it also alters the gait pattern or at least some parameters of gait that may be important in the rehabilitation process. Stolarczyk et al. studied gait parameters in THR patients depending on the size of the femoral head implant. They concluded that 36mm femoral heads offered better results in terms of gait pattern, with values that were not significantly different from healthy hips. However, a drop of the contralateral side of the pelvis during support was more common in the group where large head size was preferred than in healthy hips, both in the operated limb and healthy limb.[18]

Offset

Restoring the global hip offset (GO) in THR is incremental for maintaining optimal hip function. Medialization of the cup is not uncommon in THR, especially in cases where medial osteophytes are present. However, medialization during acetabular preparation reduces the GO. To restore the latter, a stem with a higher offset may be required (Figure 2). The compensatory increase of femoral off-

Table. Summary of the most important published related studies on gait changes in THR.

Study	Purpose	Results
Bahl et al. (11)	Changes in gait biomechanics after THR	Improvements were concluded from 6 months, with the best results appearing approximately one year after the surgery.
Naili et al. (12)	improvement in performance-based and patient-reported functions a year following THR	Objectively measured improvements in performance-based function and gait are not in line with patient-reported functional improvements
Stolarczyk et al. (18)	Gait parameters in THR patients depending on the size of the femoral head implant	36mm femoral heads offered better results in terms of gait pattern, with values that were not significantly different from healthy hips
Sato et al. (23)	The effect of GO and leg length discrepancy (LLD) on hip joint muscle strength and gait trajectory	Global FO reduction by > 5 mm after THR was associated with hip abductor muscle weakness
Tokuhara et al. (27)	Anterior knee pain after THR	Associated with increased lateral patellar tilt and leg lengthening
Renkawitz et al. (30)	The effect of LLD and offset changes after THR	Residual LLD and an FO difference greater than 10 mm led to low patient-related outcome scores and changes in gait symmetry

set (FO) is indicated because it reduces the risk of dislocation, decreases polyethylene wear, lowers the risk of edge loading and restores soft tissue tension. Moreover, restoring FO has a positive effect on isometric hip abductor strength[19], walking speed, and knee flexion and extension 1 year after THR.[20] Restored FO has also been shown to influence knee joint moments but has no apparent impact on hip joint moments.[21] Most studies have focused on the FO in relation to gait and function. However, both the FO and acetabular offset (AO) are important to consider when restoring hip joint anatomy.

Chamnongkich et al[22] suggested that a moderately increased FO may be effective for enhancing hip abductor muscle function and ambulatory balance after THR. Regardless, the abductor isometric strength was found 9% and 25 % lower in high FO and lower FO patients respectively, compared to the non operated limb. These results are in line with Sariali et al. who reported that the ROM required for activities of daily living decreased by more than 20% in patients with a 15% postoperative reduction of their offset.[20]

Further investigating the impact of offset on the postoperative gait of THR patients, Sato et al investigated the effect of GO and leg length discrepancy (LLD) on hip joint muscle strength and gait trajectory. His results showed that reduction of global FO by > 5 mm after THR, compared to the contralateral hip, was associated with hip abductor muscle weakness. He postulated that straight leg raise (SLR) strength is important for generating sufficient forward thrust when walking and that it influences the stride length and strength of the lower limb forward swing. Therefore, SLR weakness would lead to asymmetry of gait trajectory in the sagittal plane.[23]

Implant orientation

Implant orientation is crucial in THR. Despite the femoral stem anteversion (FA), the anteversion of the cup must also be taken into consideration, since the combined anteversion is of importance when considering the risk of hip impingement and dislocation. The proposed safe zone differs greatly in the literature depending on the varying geometrical definitions of the measurements as well as on the surgical approach and prosthetic types. The acetabular cup is usually implanted following the 45-degrees abduction - 15-degrees anteversion rule, whilst others use the transverse acetabular ligament as a guide for anteversion. Furthermore, when the surgeon elects a cementless type of fixation, anteverting the femoral stem according to the preoperative plan may not be feasible. Anteversion of cementless femoral stems may be restricted by the endosteal anatomy of the femoral neck, the diaphyseal bow, and the anterior-posterior isthmus at the level of the calcar femorale.[24] In addition, there has been a great debate about which is the most accurate way to evaluate intraoperatively femoral anteversion. Various reference points like the posterior condylar and transepicondylar lines, the calcar and the linea aspera have been proposed. In a study performed by Lee et al, it was supported that the femorotibial angle influenced the discrepancy between intraoperative estimation and the real FA. When the former was decreased such as in a varus knee, the intraoperative measurement underestimated the FA.[25]

Despite the abundance of articles investigating the effect of FA on hip postoperative stability, the impact of FA changes on a individual's gait pattern is not described extensively. In a recent study, Esbjörnsson et al. used computed tomography and three dimensional gait analysis to investigate whether geometrical restoration in THR leads to gait pattern alterations. They supported that changes in hip rotation during walking were associated with changes in FA in the same direction as well as changes in pelvic rotation in the opposite direction during gait.[26] Changes in rotation after THR may affect gait, daily activities, the rate of dislocation of the hip, and ipsilateral knee pain. The latter is an independent factor leading to gait alterations.[26]

According to Tokuhara et al. anterior knee pain after THR is associated with increased lateral patellar tilt and leg lengthening.[27] Furthermore, increased internal rotation of the hip may influence the axial alignment of the ipsilateral knee. There are various factors leading to increased femoral rotation. These can be associated with underlying disease (OA), less pre-operative internal rotation, female gender, posterior surgical approach, leg lengthening, and an increase in femoral anteversion.[28]

Leg length discrepancy

The occurrence of LLD is another factor leading to postoperative gait changes after THR. Marked LLD after THR is a major cause of patient dissatisfaction due to abnormal gait mechanics that lead to knee and back pain, early prosthesis loosening, and revision surgery. Beard et al. reported that patients with a LLD > 10 mm had significantly worse Oxford hip scores three years after surgery.[29] In addition, Renkawitz et al. reported that residual LLD and an FO difference greater than 10 mm led to low patient-related outcome scores and changes in gait symmetry.[30] In cases where postoperative LLD exceeds 20mm, walking speed and stride length are significantly reduced.[31] However, other researchers supported that the kinematic symmetry and loading on the hips during level walking and stair ascending were not markedly affected even when postoperative LLD was up to 20 mm. Therefore, according to them, the use of insoles in such cases was not biomechanically justified.[32]

Nevertheless, it is beyond dispute that when the leg is lengthened the tensor fasciae lata, iliotibial band, and quadriceps cross the hip and knee joint and become stretched. When the iliotibial band is stretched the patellofemoral kinematics are altered.[33] Consequently, tension is put on the lateral retinaculum thus causing increased lateral patellar tilt. Furthermore, due to changes in posture, valgus deformities may occur.[34] Especially in cases of developmental dysplasia of the hip, where leg lengthening and medialization of the hip center are combined, consequent medialization of the hip may lead to medialization of the knee. In such cases, the patient would either try to walk with a wider interfoot distance to avoid striking the contralateral side or attempt to bring the knees closer together and keep the joint line horizontal. Both of these postures may predispose the knee to valgus deformity. The postoperative mLDFA is a major factor related to knee valgus alignment after THR, which combines the preoperative anatomy and surgical reconstruction.[35] A high-offset femoral component is indicated to compensate for the medialization of the hip center.

Conclusion

Review of the related literature for the purpose of this study (Table) showed that abnormal gait patterns may persist up to 1 year after THR. Identifying gait changes after THR can offer important information about the manner the hip joint works and its impact on adjacent joints. The identification of abnormal walking patterns will help us understand their causes and will eventually make us learn how to make better decisions in our clinical practice.

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