COBEM2003 - 1558

DYNAMIC PATTERN OF TOTAL HIP ARTHROPLASTY GAIT IN SAGITTAL, FRONTAL AND TRANSVERSE PLANES

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Abstract: *The objective of this work is to establish the dynamic pattern involved in Total Hip Arthroplasty (THA) locomotion and to compare it with normal data. In this approach some assumption have been made in order to simplify de model, such as: rigid body where the movement produced by muscle, the skin and the bone deformation have been neglected and the hip's spherical model. The system VICON 140 was used for motion data acquisition, which produces an infrared strobe to detect the position of skin markers and define the segments of the foot, shank, thigh and pelvis. The ground reaction forces were measured by two platforms of force. The frequency of these equipments was set in 60 Hz. Nine patients were analyzed with one year of post-operative and the results of this analyzes are in accordance with the patterns found in the literature.*

Keywords: *gait analysis, clinical rehabilitation, total hip arthroplasty gait, human locomotion*

1. Introduction

Hip motion measurements are useful in the study of human gait. One use in the study of gait is to obtain data from patients who walk in some abnormal manner to compare them with normative data. Other use for hip measurements, obtained during walking, is to compare two or more patients who walk in some abnormal fashion.

Quantitative gait analysis has been used for numerous applications and has provided insights into functional characteristics not identifiable by clinical exam or other methods. Return towards normal function following total hip arthroplasty (THA) has been quantified by Murray in several studies (Murray, et al., 1972 e 1976; Hodge et al., 1991).

Total hip arthroplasty has been extremely successful and its usage has grown to several hundred thousand primary joint replacements per year worldwide. Implant design, methods of fixation and surgical techniques are continually changing. As usage expanded, designs involved meeting the increased functional demands of patients (Andriacchi and Hurwitz, 1997). Figure (1) presents a design of a hip's endoprosthesis.

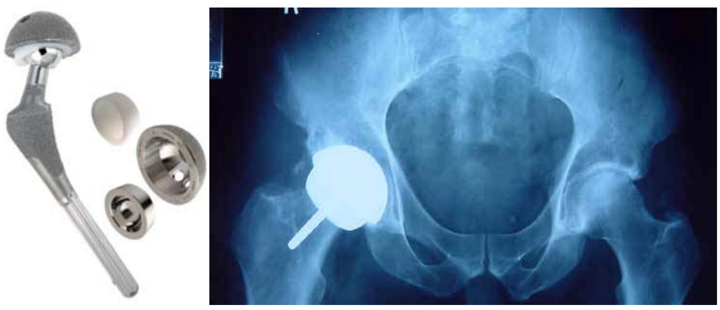

Figure 1. Hip's endoprosthesis.

Knowledge of the resultant force on the femoral head during gait is fundamental to the study of total hip arthroplasty. The force vector acting on the femoral head is dependent on the external forces acting on the limb and the internal forces primarily generated by muscle contraction. Using indirect analytical methods intersegmental forces and moments are approximated by modeling the body as a system of rigid links and measuring the three dimensional movement of the joint and the external ground reaction force (Winter, 1991; Raptopoulos et al., 2003).

In order to maintain the mechanical equilibrium during walking the muscle and soft tissues surrounding the hip joint must generate a net moment that is opposite to the external moment (Nigg, 1999). Decrease of external moments is reflective of decreased muscle force associated with decreased forces at the hip joint occurred by a trunk compensation that approximates the center of gravity to the hip.

Abductor lurch is very common in patients with hip disease. It is apparent that adequate strength of abductor muscles is required for a satisfactory gait (Winter, 1983, 1991 e 1995). Typical means of assessment of parameters relating to the mechanical performance of a muscle about a joint include cross section of the muscle, length-tension ratio, the position of the fulcrum, the length of the lever arm and the angular application of the vector force (Borja et al., 1985).

Knowledge of the motion occurring at the hip joint during walking and other activities for individuals with normal and abnormal hips should lead to an improved understanding of hip joint function. This work has been performed in Research Center of the Human Movement-CPMH/INTO-MS - Rio de Janeiro-Brazil. This study involves the kinematics and kinetics in the sagittal, frontal and transverse planes of the hip joint after total hip arthroplasty with one year of post-operative and compared with the normal data (Raptopoulos et al., 2003).

2. Definitions

Total hip arthroplasty, as originally introduced by Charnley in the 1950s, was typically prescribed only for patients who were older than sixty-five years and had gross disablement (Charnley, 1961). Now the durability and the improvement in the techniques turn this proceeding very common in younger patients. THA has had great clinical success in providing patients with improved comfort and quality of life.

THA is a technique that substitutes the head and neck of femur and introduces an acetabular cup in the pelvic. Figure (2) illustrates a total hip replacement with an acetabular metal cup fixed in the pelvic with a modular ceramic femoral ball joint.

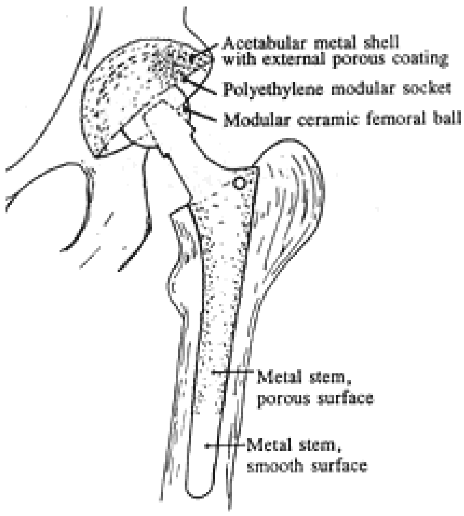

Figure 2. Representation of a total hip arthroplasty.

Different approaches of uncover the hip joint have been described with the goal of minimizing soft tissue and muscles dissection. Unfortunately all approaches that dissect the abductor and extensors muscles of the hip turn these muscles weak. The extensor and the abductor muscle are very important to accomplish efficient walking. Some abductors muscles are external rotators and others are internal rotators and their weakness induces either disability in the frontal and transverse plane.

A gait analysis by phases could identify the functional significance of the different motions occurring at the individual joints. The phases of gait also provides a means for correlating the simultaneous actions of the individual joints into patterns of total limb functions (Perry, 1992). This is a particular important approach for interpreting the functional aspects of disability in the hip on the sagittal, frontal and transverse planes.

Function at the hip differs from the others joints in several respects. The hip represents the junction between the locomotors units and the trunk. As a result, it is designed to provide more overtly three-dimensional motion with specific muscle control for each direction of activity. Sagittal plane motion involves the largest arc, while muscular requirements are brief. In the frontal plane, motion is limited, but the muscular demands are substantial. Transverse plane rotation remains a subtle event (Inman et al., 1981; Perry, 1992).

In the sagittal plane the hip moves through only two arcs of motion during a normal walking: extension during stance and flexion in swing. The exchange of the motion from one direction to the other is gradual and a normal arc of hip motion average is 40º. Throughout stance the body weight vector moves backward from an initial position anterior to the hip joint. Peak of flexion torque at the hip occurs at the onset of limb loading and the extensor muscles work to reduce these external moments. Figure (3) illustrates the loading response phase with the representations of ground reaction force and extensor muscles action in hip and knee.

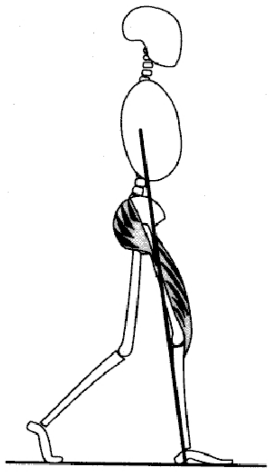

Figure 3. Ground reaction force in loading response phase.

In the frontal plane the hip moves through a small arc of adduction and abduction as the unloaded side of the pelvis follows the swinging limb. Initial floor contact is accompanied by a brief and small laterally ground reaction force. As limb is loaded the ground reaction force promptly reverses to a medial alignment. Throughout the rest of stance period, this external adducting vector is maintained. Figure (4) illustrates the ground reaction force during mid stance. Basically the alignment is between the center of the foot and the midpoint of the pelvis. This external adductor moment cause a pelvic drop that must be balance by abductor muscles.

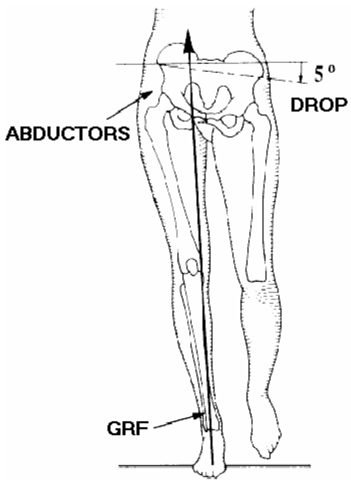

Figure 4. Ground reaction force in the mid stance phase.

In the transverse plane the hip moves through an arc of internal rotation followed by similar arc of external rotation.

3. Materials and Equipments

The motion analysis was performed using a computer-aided video motion analysis system with three infrared cameras (VICON 140) and two platforms of force (Bertec Co.). These equipments were set in 60 Hz. The walking way and the equipments of the gait lab are presented in the Fig. (5).

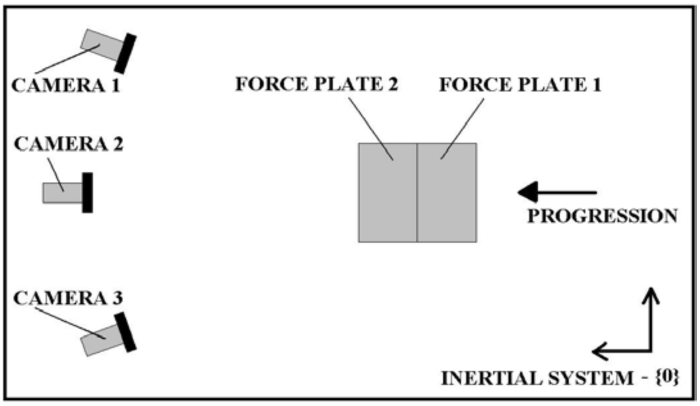

Figure 5. Walking way and equipments of the gait lab.

The results that will be presented in this work were obtained through the analysis of 9 elderly patients with one year of post-operative of Total Hip Arthroplasty. The THA group was formed for 5 men and 4 women and has the following characteristics: 54.3 ± 14.7 years old, 1.65 ± 0.09 m of height and 72.56 ± 17.86 kg of weight. All subjects have a free walking. They do not use crutches to help in walking. To supplement the analysis a video data was captured to identify trunk inclination.

4. Experimental Protocol

We used the same protocol of marks that was defined in Raptopoulos et al. (2003a), where the following anatomical points were employed: the medial area of the feet, the long axis of the feet, the lateral and medial malleolus of the ankles, the anterior surface of the shanks, lateral and medial epicondyle of the knees, the vertexes of pelvis' reference structure, the anterior-superior iliac spines of the pelvis.

The subjects had their gaits captured three times to obtain a medium value and a good estimation of each kinematics and kinetics parameter.

5. Results

The Figure (6) shows the hip's movement of each of the 9 THA subjects and the mean and respective standard deviation of normal data. The gross black line and point black line represents the mean and the standard deviation of normal data respectively. While the Figure (6.a) shows de movement in the sagittal plane in one cycle, the Fig. (6.b) and Fig. (6.c) show the movement in the frontal and transverse planes in one cycle.

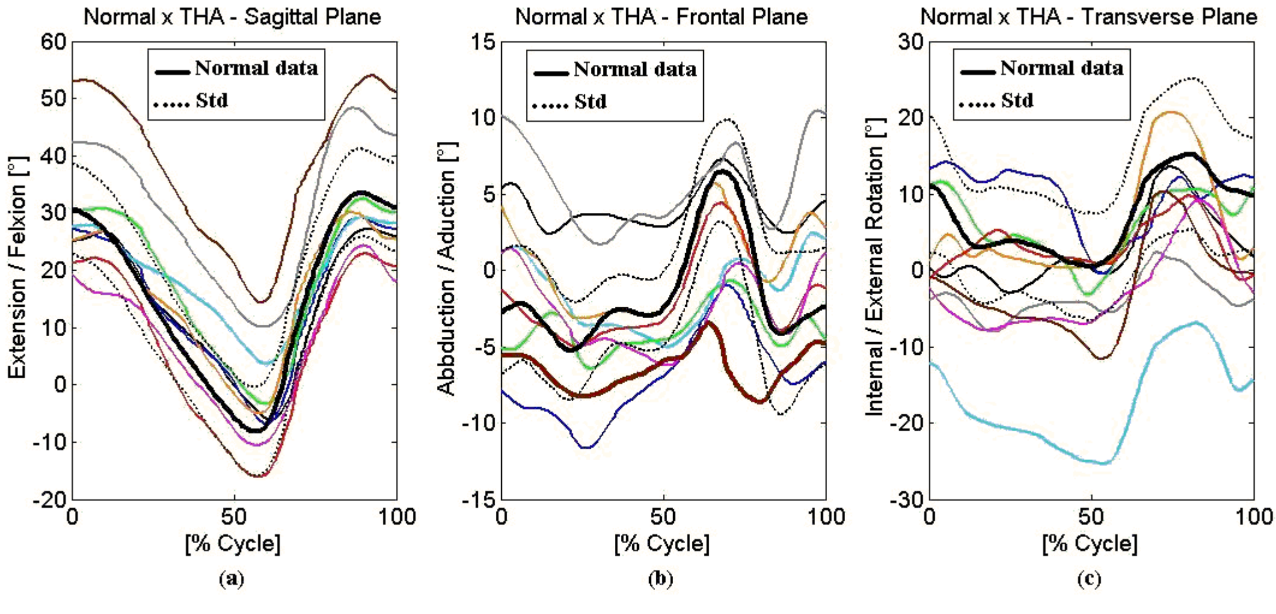

Figure 6. Movement of the hip after one year post-operative with THA.

The hip's external moments of each of the 9 THA subjects and the mean and respective standard deviation of normal data are represented in fig (7). The gross black line and point black line represents the mean and the standard deviation of normal data respectively. While the Figure (7.a) shows de external moment in the sagittal plane in one cycle, the Fig. (7.b) and (7.c) show the external moment in the frontal and transverse planes in one cycle.

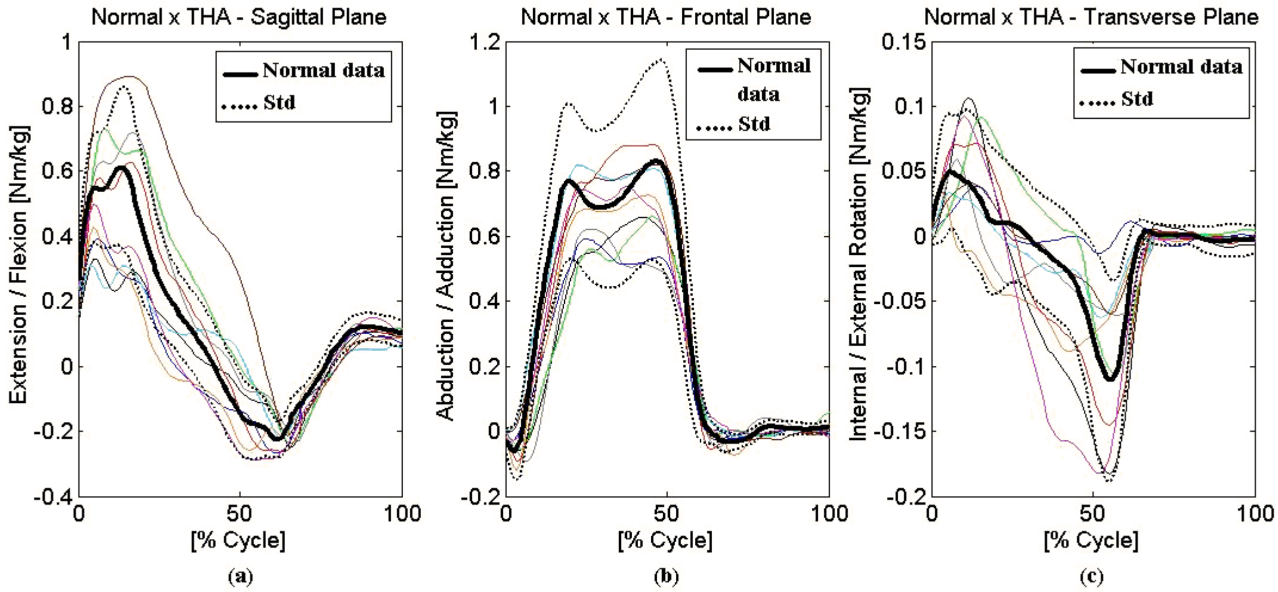

Figure 7. External moments in the hip after one year post-operative THA.

The Figure (8) shows the force in the hip of each of the 9 THA subjects and the mean and respective standard deviation of normal data. The gross black line and point black line represents the mean and the standard deviation of normal data respectively. While Figure (8.a) shows de force in the sagittal plane in one cycle, the Fig. (8.b) and (8.c) show the force in the frontal and transverse planes in one cycle.

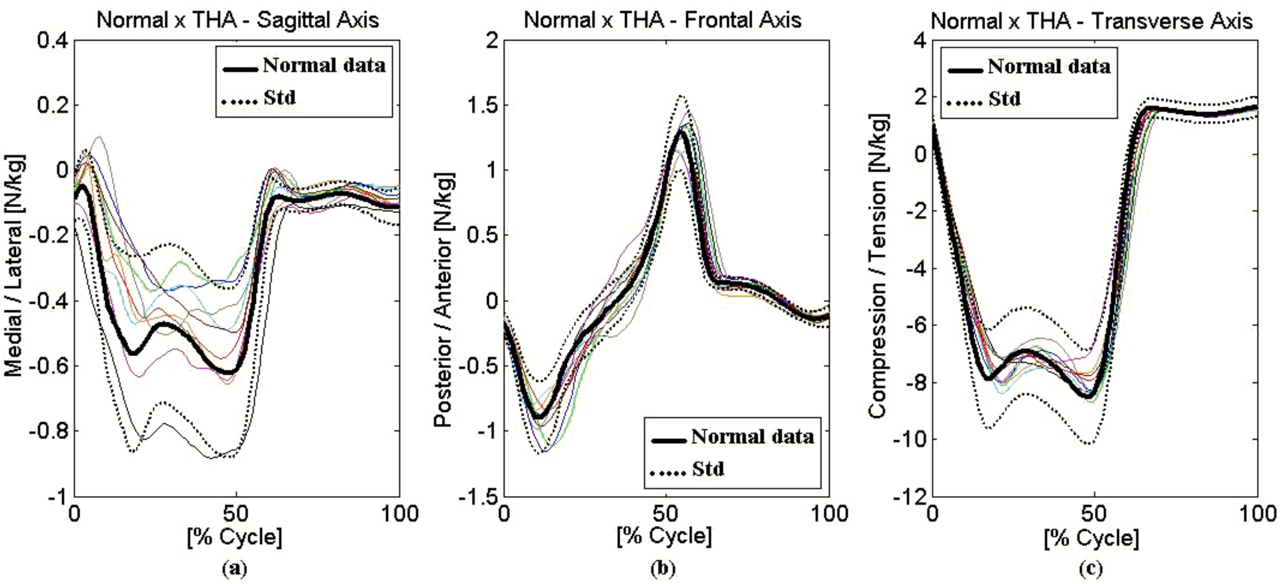

Figure 8. Force in the hip after one year post-operative THA.

6. Discussion and Conclusion

To analyze if there were differences between the subjects who had THA with the normal one a comparison in the dynamic field was made. Previous studies have shown that patients have considerable improvement in walking ability following THA surgery but not to the level to be considered normal.

Some gait analysis studies (Murray et al., 1972; McGrouther, 1974; Murray et al., 1976) have suggested that the total hip Arthroplasty patients do not achieve completely normal function before 6 months following the surgery. Others studies (Hodge et al., 1987 e 1989) demonstrated that the kinematics returned at near normal values at 1½ year after surgery.

Figure (6) shows the motions of the hip in sagittal, frontal and transverse plane. The greater variability occurs in the frontal and transverse plane. In the sagittal plane a reduced arc of motion was observed in all subjects and two of then are outside of the positive standard deviation.

Figure (7) shows the external moment and more attention must be considered in the frontal plane. In spite of all subjects are inside de standard deviation a singular aspect could transform the analyses: the shape of the curve. Most subjects have missed the first adduct maximum peak because of the compensatory strategy. This compensation occurs to minimize the external moments in the opposition to muscles weakness (Inman et al., 1981; Kapandji, 1980; Berme and Cappozzo, 1990; Perry, 1992).

Figure (8) shows the force in the hip. The results are very consistent and in accordance with the normal data. The cadence and velocity could interfere in force (Murray et al., 1966; Andriacchi et al., 1977; Kadaba et al., 1990), i.e. more velocity induces more force. The normal data was obtained with slow cadence and velocity and the THA group shows a similar cadence.

Observing all results, the subject represented by the brown line has a worst performance compared to the others, specifically in the sagittal plane. The flexor external moment is very high and the hip is flexed in accordance with the extensor muscle weakness.

Some of subjects exhibited excessive pelvic drop while others used a compensation strategy involving trunk inclination. The THA patients in this study had no supervised strength training and rehabilitation following surgery.

The influence of the type of surgical approach must be investigated by comparing the postoperative data of patients who had undergone THA either by an anterolateral approach or posterolateral approach (Murray et al., 1976). The two approaches affect different muscles, witch led to the hypothesis that the two groups would have different postoperative gait.

In this work were presented and discussed some important parameters for gait analysis and clinical rehabilitation. For a complete study and better results is necessary to analyze more subjects of each group, mainly of the THA group of control.

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