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SPECIFIC METHODS OF HIP IMPLANT NON-INVASIVE ASSESSMENT

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Abstract: *Patients with hip implants need to be evaluated both before the surgery and after a given time from the surgery (6 weeks, 3 months, 6 months) in order to observe the outcome and response following the intervention. The present paper presents some specific methods that can be designed, supervised and used by medical engineers in collaboration with medical staff, providing thus objective results regarding the evolution of patients with hip implants. This way the bias of the self reports and questionnaires presently used can be eliminated and a thorough analysis of the surgery outcomes is possible.*

Key words: *hip implant, balance, gait analysis.*

1. Introduction

There is a general concern regarding the evolution of patients with hip implant, after the operation, therefore several assessment methods have been used in order to rate the benefits of the intervention and the influence upon the patient's life quality.

Most of the evaluation methods described by specialized articles refer to questionnaire methods like QWB (Quality of Well Being) SF-36 (Short Form 36) or WOMAC (Western Ontario and McMaster Universities Osteoarthritis Index). These methods provide an estimate of the perceived disability for a given disease [1] based upon patients' self reports.

They have the advantage of easy administration, they are inexpensive and provide multiple results in a single test but at the same time they are biased at a certain level, due to patients' expectations, memory errors or impaired cognition. [2]

The team aims at developing specific and objective methods and to use them experimentally for the evaluation of gait and balance of persons subjected to hip implants. The results may help medical staff to develop targeted exercises and rehabilitation methods in order to improve the patient's life quality.

2. Objectives

Hip arthroplasty is meant to remove the dysfunctions emerged due to medical problems like: osteoarthritis, osteoporosis, rheumatoid arthritis, etc. or as a result of traumatic accidents. [3]

The intervention outcome depends on many factors and should be carefully monitored taking into account individual characteristics.

This is the reason why many researchers and experts tried to find suitable methodologies to evaluate the evolution after a hip arthroplasty.

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Many methods are based upon gait analysis used to determine gait adaptations for many years. [4]

Also it was found that physical performance measurements have an important role in the evaluation of outcome in patients undergoing hip arthroplasty. [5]

According to [6] there are variable definitions regarding the outcome of a total joint replacement surgery and responsiveness is a major element that shows which patient benefits from this procedure because subtle changes in patient's behaviour can be determined.

Therefore, the goal of the present research is to develop personalized non-invasive methods of investigating patients subjected to hip arthroplasty in order to monitor their evolution and offer valuable information to the medical staff.

3. Materials and Methods

The subject of our investigation was a 56 years old male subjected to a hip arthroplasty one year ago. Although the medical tests and X-rays were looking good, the person complained of muscle pains in the hip and upper limb, especially when climbing stairs. The medical staff decided that further investigations were required.

In order to be able to investigate the proposed subject, the team developed a personalized procedure based upon the general protocols used for this type of testing.[7]

Thus, usually static and dynamic tests are performed, using specific equipment like force platforms (Kistler) and/or pressure platforms (Footscan).

Static experiments involve the analysis of subject's balance for 30s while standing on the platform in small, intermediate and large base of support (fig.1, fig.2). The subject is instructed to be relaxed, look ahead and avoid movements.

Fig.1. *Static balance, small base of support*

Fig.2. *Static balance, large base of support*

Dynamic experiments are performed using both Kistler force platform and Footscan pressure plate in order to corroborate results. The subject is instructed to walk normally (fig.3) or in different other manners according to his health problems. The studied subject was instructed to walk over an obstacle (fig.4) in order to simulate stair climbing and to maintain balance on a single foot in order to assess the strain in the affected limb. Also the subject was asked to walk laterally (fig.5) as he claimed pains when moving the lower limb in the frontal plane.

Fig. 3. *Subject walking normally on Footscan*

Fig .4. *Subject avoiding an obstacle during walking*

Fig. 5. *Subject walking laterally*

Every experiment was repeated three times in order to obtain as accurate results as possible and each type of motion was studied both when the subject started with the right foot (the affected one) and with the left foot (the healthy one).

4. Results and Discussions

By using the Kistler force platform connected to a laptop provided with Bioware software, we are able to determine the forces along the axes Ox, Oy and Oz, also the moments around the same axes and the positions of the COM projections on the ground allowing the representation of the stability area.

It was considered that the most representative ones are forces on the axis Oz as they express in fact the ground reactions and also the stability area whose extension shows the manner of maintaining balance when standing in an upright relaxed position.

In fig. 6 and 7, the representation of the ground forces Oz and also the stability area is shown for a small base of support, which is the most difficult when it comes to maintaining balance.

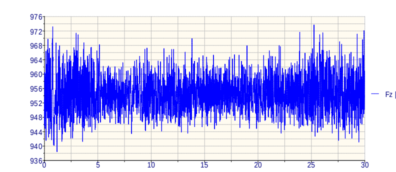

Fig.6. *Representation of the force Fz for small base of support*

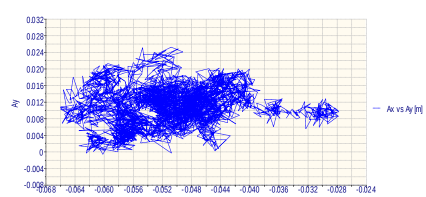

Fig.7. *Representation of stability area for small base of support*

Before the start of measurements, the platform is calibrated and the subject is weighed (G=953,4N).

By analyzing the obtained diagrams it was found that the value of the forces between the foot and the ground are Fz_{min}=938,4N to Fz_{max}=973,7N exhibiting an average very close to the subject's weight and proving a good distribution of weight upon the feet surface.

The stability area shows a variation of 0,0258m showing a good balance and a small amplitude of the natural body oscillations during the attempt of maintaining equilibrium in a small area.

The results obtained for large base of support are approximately in the same range, revealing a reaction force Fz_{min}=933,3N to Fz_{max}=975,7N, with an average of 953,1N which is almost the same with the subject's weight.

The analysis of the stability area leads to a variation of the COM projection positions of 0,027m very close to the one obtained in small base of support.

After observing that the static measurements when standing in a normal posture, with both feet on the ground are normal, the next step was to determine the equilibrium when the subject stand on one feet in order to perform a comparison between the healthy and the operated leg.

In fig.8 the representation of the reaction force Fz for the right foot (the affected one) is represented, while in fig.9 the stability area is shown for the same foot. It was of more interest to present the diagrams for the lower limb that was under study, though the measurements were made for both.

The maximum value of the reaction force Fz reached 988N proving an additional effort when the subject is leaning only on the operated limb while the maximum value for the healthy limb reached only 976,5N, very close to the one measured for standing on both feet.

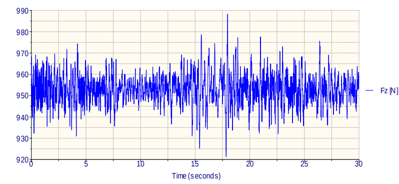

Fig.8. *Diagram of reaction force Fz for balance on the affected limb*

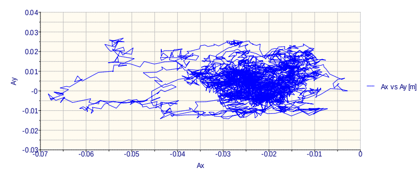

Fig.9. *Stability area for balance on the right limb (operated)*

The analysis of statistic data obtained from the stability area shows that the range of the COM projections reaches 0,041m, unlike the range for the left limb, which was around 0,032m. The difference does not seem very significant but a value of almost 1cm higher in the body oscillations amplitude is to be considered.

The dynamic measurements were made using both platforms.

Kistler force platform was used for normal walking, only one step being possible due to the small size of the platform. The subject was asked to start walking three times with the right foot and three times with the left one and the pattern of the forces on all axes was analyzed, especially as far as the reaction force Fz is concerned.

Two wooden platforms were placed on each side of the Kistler platform in order to avoid the level difference with the ground (the step effect) and avoid unwanted errors in the measurements.

Thus, in fig.10 the diagrams of the forces Fx, Fy and Fz are shown for the situation when the subject starts with the right foot while in fig.11 the same diagrams are presented for the start with the left foot.

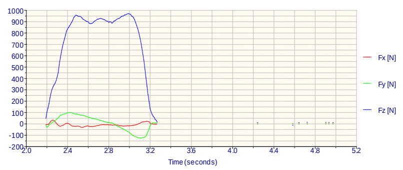

Fig.10. *Forces diagrams for the start with right foot*

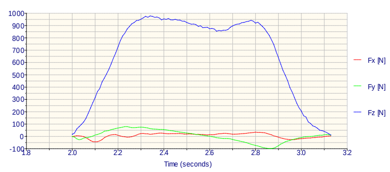

Fig.11. *Forces diagrams for the start with the left foot*

The aspect of the two diagrams is very important as it clearly shows a very short contact of the right foot with the ground by comparison to the left foot and during the middle phase, when the sole is rolling on the floor the reaction force shows a certain increase due to the fact that there was too much pressure upon the respective limb but for a shorter time interval.

The FootScan RSScan platform designed for determining plantar pressures is from certain point of views more suitable for dynamic investigations due to its length (2m) allowing the subject to perform even three steps. It is recommendable to cover the platform surface with some plastic rugs for example in order to avoid biased determinations (the subject is not walking naturally and usually tries to walk either too slow or too fast). The information are processed by help of dedicated software and can be displayed either by graphical or by numerical forms.

Graphical forms are definitely more expressive, warm colours indicating higher plantar pressures while cold colours indicate lower values of the plantar pressures.

In fig.12 the plantar pressures are shown for the situation when the subject overpasses the obstacle using the right foot and in fig.13 the plantar pressures are shown for the start with the left foot.

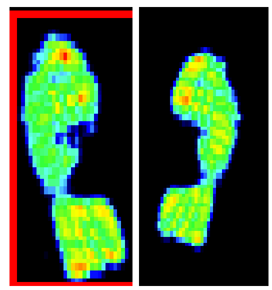

Fig.12. *Plantar pressures during stepping over an obstacle with the right foot*

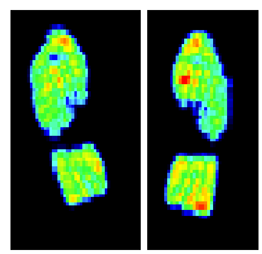

Fig.13. *Plantar pressures when stepping over an obstacle with the left foot*

Another type of walking that was recorded in order to analyze the hip joint mobility in frontal plane was lateral walk. The plantar pressures are presented in fig.14.

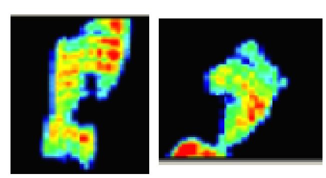

Fig.14. *Plantar pressures representation during lateral walk*

When stepping over the obstacle, it becomes obvious that the subject is pressing harder on the foot opposed to the one that is used for starting the motion. This happens due to the fact that he has the tendency of stepping very carefully over the obstacle so the plantar pressure is lower and then he relaxes during the next step, so the pressure is increased.

During lateral walk a higher pressure is exhibited, as the subject claims to suffer pains while moving the hip joints in a frontal plane.

4. Conclusions

Medical engineering methods can be a serious help for the medical staff due to the non-invasive and thorough investigation and analysis that are able to determine the shortcomings and benefits of various interventions.

For the studied case the conclusion was that the surgery accomplished its purpose, which is also proven by the X-rays showing a total healing. The pains are due to an unsuitable development and use of the muscles in the affected limb, as the only discrepancies occur during the dynamic measurements, the static ones being normal.

The cause of the abnormal muscular actions is generated by the fact that the subject did not respect entirely the gymnastics program recommended by the medical advisors. So, in this respect the subject was advised to resume physical training and perform exercises for developing the back and lower limbs muscles.

Acknowledgements

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References

1. Shields, R., Enloe, L., Leo, K.: *Health Related Quality of Life in Patients with Total Hip or Knee Replacement.* In: *Archive of Physical Medicine and Rehabilitation,* vol.80, USA. 1999, p. 572-579.
2. Van den Akker-Scheek, I., Zijlstra, W., Groothoff, J.W., Bulstra, S.K., Stevens, M.: *Physical Performance Before and After Total Hip Arthroplasty: Perception and Performance.* In: *Physical Therapy Journal*, no.6, vol.88, 2008, p.712-720.
3. Cotoros, D., Repanovici, A., Baritz, M., Stanciu, A.: *Modeling and Simulation of Gait by Anybody Software before and after Hip Arthroplasty.* In: *E-Health and Bioengineering Conference (EHB)*, Iasi. 2015, p. 101-105.
4. Ewen, A., Stewart, S., St.Clair Gibson, A., Kashyap, S., Caplan, N.: *Post-operative gait analysis in total hip replacement patients—A review of current literature and meta-analysis* In: *Gait&Posture*, vol.36. 2012, p.1-6.
5. Kennedy, D., Stratford, P., Wessel, J., Gollish, J., Penney, D.: *Assessing stability and change of four performance measures: a longitudinal study evaluating outcome following total hip and knee arthroplasty*. In: *BMC Muskuloskeletal Disorders*. 2005
6. Kreibich, D.N. et.al.: *What Is the Best Way of Assessing Outcome After Total Knee Replacement?* In: *Current Orthopaedic Practice*. Lippincott-Raven Publishers. 1996
7. Egoyan, A., Moistsrapishvili, K.,: *Equilibrium and Stability of the Upright Human Body*, In: *The General Science Journal*. 2013 Tbilisi, Georgia