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Gait Analysis of a Subject with Total Hip Arthroplasty

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Abstract

Introduction: gait analysis of a subject with total hip replacement is described. Objective: instrumental gait analysis of a subject 12 years after the total hip arthroplasty. **Materials and Methods:** in a movement analysis laboratory, locomotion studies were carried out at freely chosen walking speed by a 64-year-old subject, obtaining kinematic, kinetic and surface electromyographic data in time and space. All measurements were assessments by applying walking protocols on a straight surface of 8 m long. **Results:** abnormal slight activations of semitendinosus and tibialis anterior muscles, of the left limb, were observed throughout the gait cycle, no spatiotemporal parameters far from normal values were detected. **Conclusions:** it was possible to obtain an exhaustive analysis of the parameters associated with the gait of a subject after 12 years of total hip arthroplasty.

Keywords

Total Hip Arthroplasty, Kinetics, Kinematics, Surface Electromyography, Motion Analysis Laboratory, Pathological

1. Introduction

Total hip arthroplasty (THA) is an excellent procedure for preserving gait when alternative solutions are not feasible [1]. However, it is important for both medical staff and patients to understand the quantitative biomechanical changes that occur after replacement procedures [2] [3]. To analyze and understand the kinetics and kinematics of these changes, motion analysis is useful [4] [5].

The indication for THA is based on disabling symptoms and underlying disease, most often related to osteoarthritis of the hip that causes an alteration in normal kinematic patterns mainly due to pain [5] [6] [7].

At present, there are difficulties in accessing quantitative information related to gait in subjects with THA in the region, but there are reports with qualitative results focused on the observational clinical evaluation of gait and the use of clinical scales [8] [9].

This work focuses on complementing these results with the quantitative analysis of gait in a gait analysis laboratory of the Universidad Tecnológica Sur Oeste (UTEC-SO).

2. Materials and Methods

Case report

Cross-sectional single case study of a 64-year-old male, height 1.76 m, weight 75 kg; he was diagnosed with osteoarthritis of the hip at the age of 32. He underwent recession and prosthesis placement in both hip joints 12 and a half years prior to this study. He has an extensive history of performing. He is currently engaged in non-intensive physical activity, so his physical condition is good. He does not suffer from any other chronic pathology.

In all stages of the study we proceeded in accordance with the international recommendations on clinical research (Declaration of Helsinki of the World Medical Association, as stipulated in its latest amendment). Authors have checked with UTEC to make sure the study was complying with the specific requirements of the institution. Institutional review board explicitly approved any doubtful aspects of the study.

Measurements and procedures

Eighteen repetitions were performed for each of the following protocols for gait analysis:

- 6-meter straight line gait,
- 6-minute walk in circles,
- 5-minute walk on a walking treadmill, (**Figure 1**).

Figure 1. Treadmill walking test.

Gait was evaluated with instrumental technologies of the BTS Bioengineering® digital ecosystem which allow an objective analysis of gait from spatiotemporal kinematic, kinetic and muscle electrical activity recordings (surface electromyography EMGS). The applied BTS Bioengineering® system consists of a wireless inertial sensor (G-WALK®), eight wireless cells for surface electromyography measurement (FREEEMG 1000®), four digital force platforms for dynamic gait analysis (BTS P-6000) and a video graphic system with passive markers and eight infrared cameras (SMART DX®) [10].

The study parameters consisted of the following gait assessment indexes obtained with the BTS® ecosystem: G-Walk ®

- **Gait cycle quality index (GQI):** indicates the subject's ability to subdivide the gait cycle performed by each limb into the correct proportions of stance (60%) and swing (40%).
- **Global symmetry index:** evaluates whether both right and left limbs globally perform the respective gait cycle symmetrically in terms of the duration of the stance and swing phases.
- **Symmetry index (SI)**: represents the patient's ability to accelerate the center of mass in a similar manner during the right and left gait cycle. A score equal to 100 represents a completely symmetrical gait.
- **Propulsion index (PI):** describes the (propulsion symmetry) ability of the patient to fully accept (transfer) the body weight to the leg after the deceleration phase and to push the center of mass forward on the contra lateral leg (deceleration phase).

Those obtained with the BTS® ecosystem: SMART DX®.

- **Gait profile score (GSP):** is calculated as the Euclidean distance between the kinematic gait parameters and their corresponding normalized values for the entire gait cycle. Values greater than 7 indicate gait compromise.
- **Gait deviation index (GDI):** greater than 100 indicates a subject whose gait characteristics are statistically indistinguishable from the gait of the control group. A value greater than 100 indicates a normal subject.

Statistical analysis

SMART capture, SMART tracker and SMART analyzer softwares from the BTS Bioengineering® ecosystem were used for quantitative gait analysis.

3. Results

The study of the subject's gait characteristics is initially presented by analyzing the spatio-temporal graphs obtained (**Figure 2**).

The stance phase time of both limbs is below normal, which is also noted in the swing phase and stride time. The stride length of both limbs is above normal, which in turn is verified in the average velocity graph.

For the gait assessment indexes (**Figure 3**), a GSI in accordance with normal is observed together with an SI below normal. The mean GQI of the right limb is within the range of normal, while for the left limb it is below the range of normal. The propulsion of the left limb is lower than the right. The gait profile score

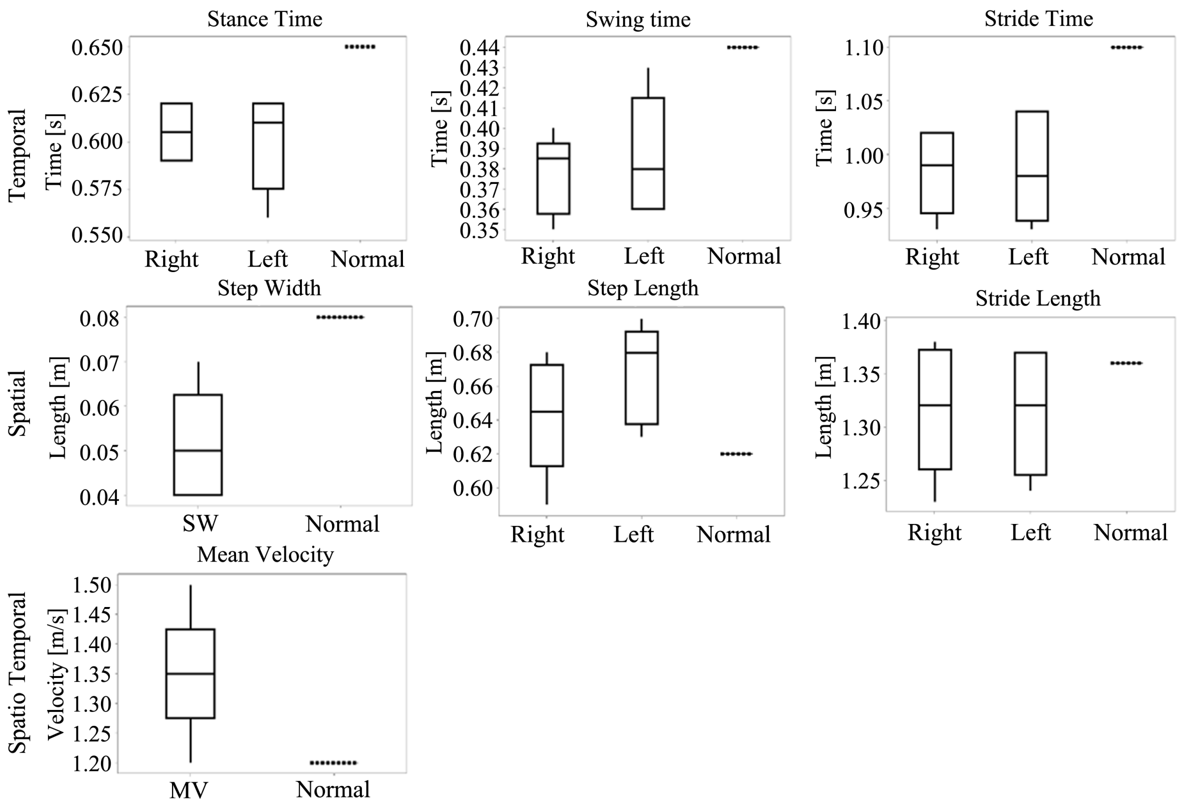

Figure 2. Box plot graphs of spatial temporal parameters measured for gait cycle on right and left legs.

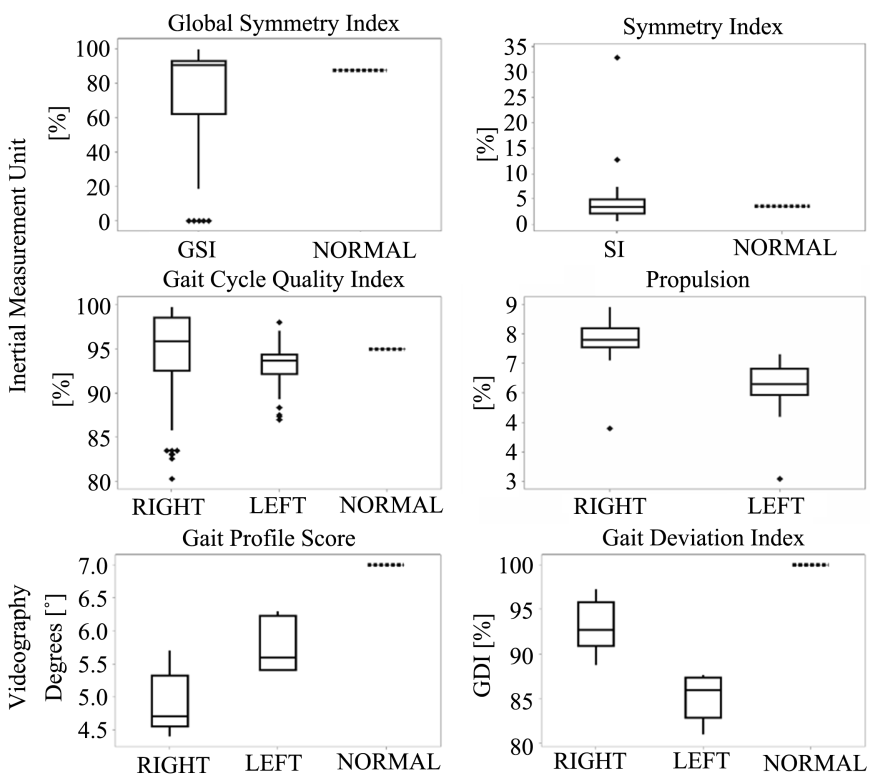

Figure 3. Box plot graphs of gait evaluation indexes measured for gait cycle on right and left legs.

is below the pathologic level for both limbs but the gait deviation index is below the normal level indicating a pathologic range.

It is important to analyze the trunk inclinations (**Figure 4**) especially because it is where significant variations are seen, which influence and trigger compensations in gait, it is in the hip obliquity graph where asymmetry is noted.

In the analysis of the kinetic parameters, no considerable deviations from normal behavior were observed (**Figure 5**). A slight deviation of the flexion-extension moment of the knee of the left leg at the beginning of the support is observed. The hip movements demonstrate an irregular movement pattern. This occurs during the beginning of the stance phase and the middle of the swing phase.

The muscular work in the lower body represented by means of the average activation profiles in the antagonistic pairs of the thigh and calf shows inconsistencies in the activation times with respect to those shown by the control group for the macha cycle, see (**Figure 6**). In normal conditions the tibialis anterior acts during the toe-off phase and also in the braking of the foot on the ground. In the left limb the tibialis anterior presents an anomalous muscular activation during the whole cycle. In the analysis of the activity of the gastrocnemius muscle, a quasi-biphasic activation was observed in both limbs that does not respond to the normal pattern (monophasic), associated with half of the stance phase shown in the normal activation interval of this muscle acquired in a group of healthy subjects matched in gender and age range. In the analysis of the muscle activity corresponding to the thigh, it was observed that the contraction of the rectus femoris at the instant corresponding to the initial contact of the heel with the floor prevents knee flexion.

In the case of the subject, a tendency to activation is seen that corresponds to normal behavior in the two extremities. The muscles of the back of the thigh act in phases very similar to the anterior muscles, but their activity starts and ends a little earlier. They ensure deceleration during leg extension and control knee rotation. It is precisely in the muscle activity of the patient's semitendinosus

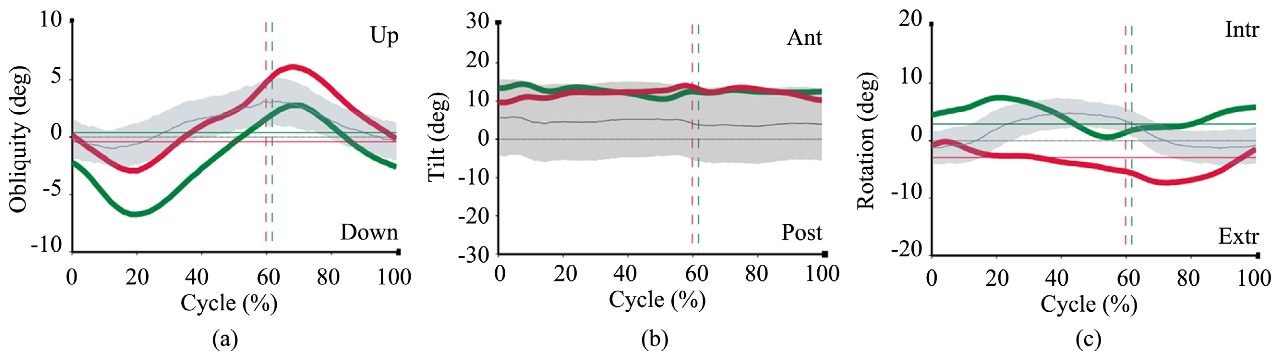

Figure 4. Representation of hip obliquity in its frontal plane (a), inclination in its sagittal plane (b), rotation in its transverse plane (c) of the right and left lower extremities, (green and red continuous line respectively). Those representations are compared with respect to the mean values (shading) of a control group with the same age range (0 to 64 years) as the patient, during a 100% normalized gait cycle.

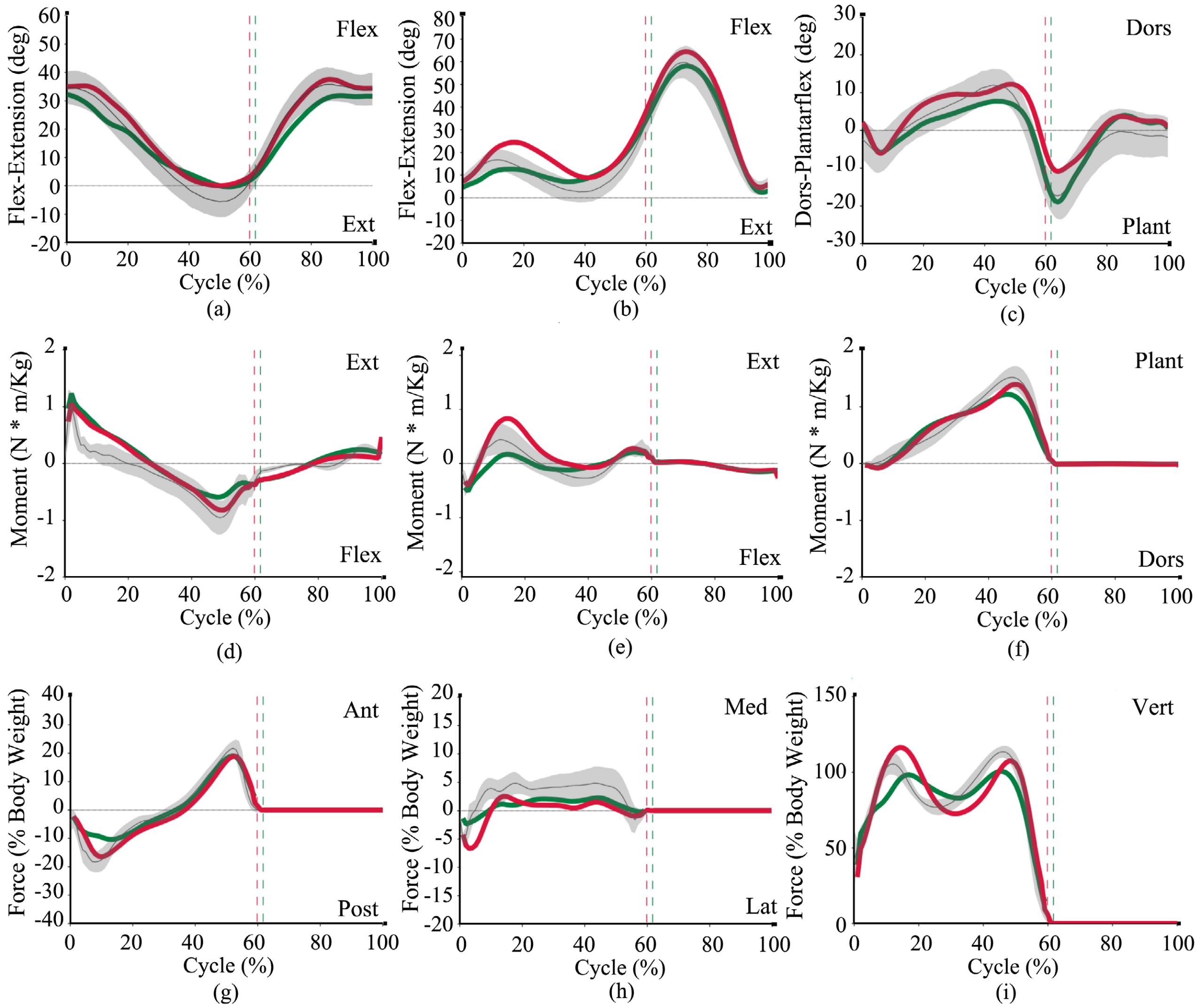

Figure 5. Representation of the angular displacements of the hip (a), knee (b), ankle (c), moment of force of the hip (d), knee (e), ankle (f) and mechanic power on areas: antero-posterior (g), medial-lateral (h) and vertical (i) in the sagittal plane of the right (continuous green line) and left (continuous red line) lower extremities. Those representations are compared with respect to the mean values (shading) of a control group with the same age range (0 to 64 years) as the patient, during a 100% normalized gait cycle.

where a greater deviation from the normal activation pattern is observed, with a spastic contractile tendency being observed throughout the entire cycle. In the right semitendinosus, activation was observed starting at 60% of the gait cycle, dropping at approximately 85% and returning to normal activation. In the left semitendinosus, a markedly abnormal activation was observed throughout the gait cycle, particularly in the middle of the stance phase.

4. Discussion

While studies that have evaluated and described gait patterns in patients after THA have been published, this study focuses on describing variations in gait patterns due to prolonged use of prostheses in both hips 12 years after implantation.

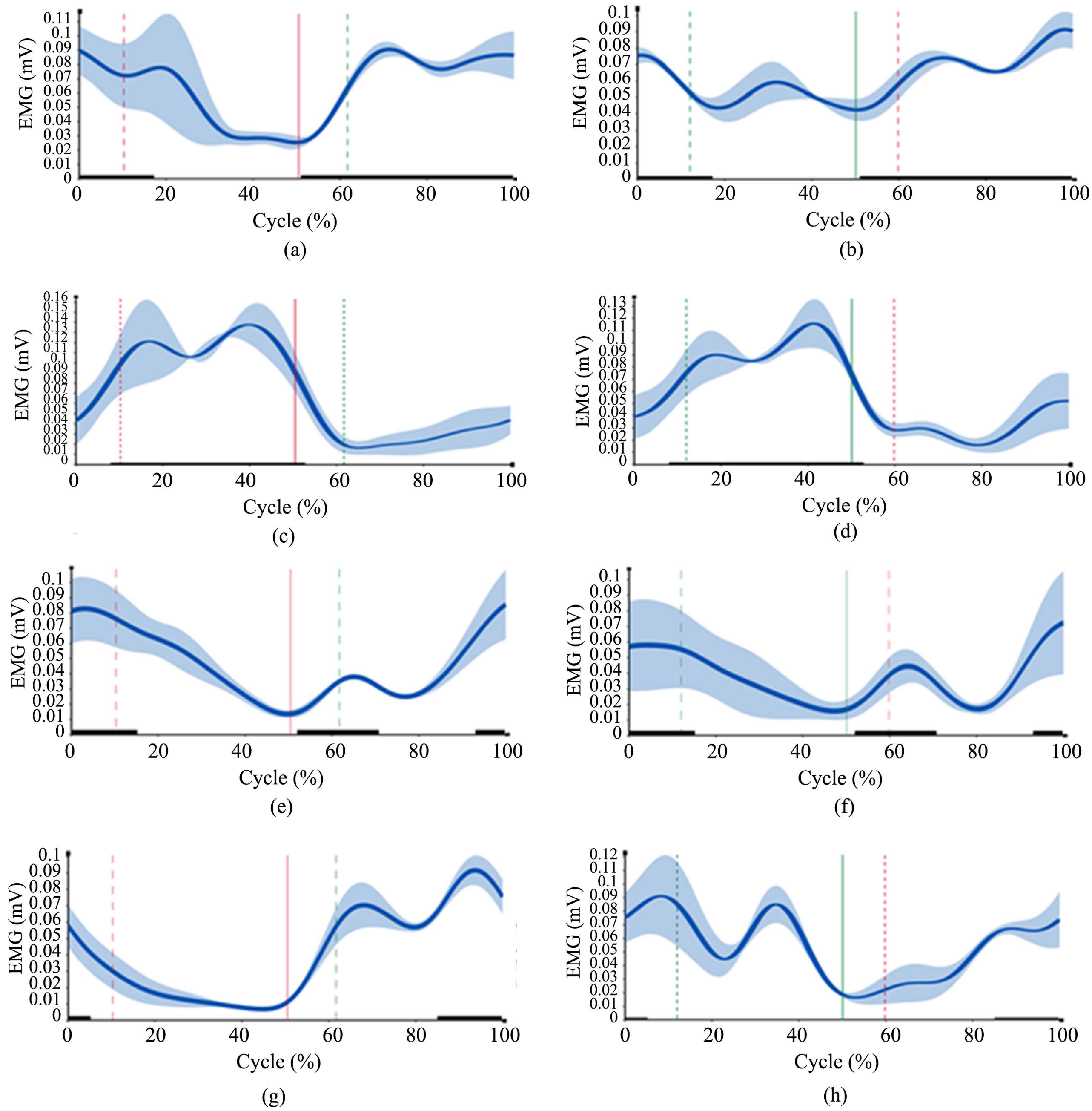

Figure 6. The electromyography profiles of: tibialis anterior (a), gastrocnemius lateralis (b), rectus femoris (c), semitendinosus (d). On the right column the data for the left lower extremity and vice versa. Presented in ascending order, during a normalized 100% run cycle. Contrasted the mean muscle activity corresponding to a control group (shaded) with the same age range (0 to 64 years) as the patient, and the mean muscle activity (continuous line) of the patient for each of the specified muscles in the figure.

For this purpose, studies were performed under laboratory conditions and specific methods for instrumental measurement were applied. The evaluation and analysis of gait deviations were performed by contrasting the variables with those obtained in a group of normal subjects, analogous in gender and age range. The kinematic patterns of the patient's gait did not differ significantly from those observed in the control group; however, abnormal behavior of the muscular activity and kinetic variables was observed during the stance phase of the foot. The correspondence of the spatiotemporal parameters with the normality intervals of the control group reflects the good quality of the surgical replacement procedure and of the post-operative rehabilitation, added to the good quality of life of the patient throughout the 12 years, with the systematic practice of low-intensity physical exercise. The patient's average gait speed exceeds the one shown by the control group. In contrast, previous reports showed that patients with CTA had reduced gait velocity during the early postoperative period. The normal kinematics observed is reflected in the PPM value, which is below the pathologic value (left PPM = 5.7 < 7 and right PPM = 4.7 < 7), the left PPM is closer to the pathologic value. This proves that the kinematic behavior shows a slight tendency to asymmetry between the left and right limbs. Small variations from the normal hip flexion-extension behavior are observed in the study, resulting in a slightly anomalous lateral trunk tilt (**Figure 4**). This observed behavior resembles the one obtained by other authors who have reported that gait efficiency decreases, with an increase in lateral trunk displacement after THA [11]. Analyzing the variations in the hip, knee and ankle joints, a tendency to normal behavior can be observed with an abnormal behavior observed in the knee in the initial stance phase (**Figure 5(b)**), where the left knee flexes unequally to the right during heel contact. The behavior of the force moments corresponds to the normal pattern with a small asymmetry between both limbs, which supports the small deviation of the trunk to the left side. The analysis of the parameters shows the possible manifestation of a compensation mechanism towards that side almost imperceptible to the naked eye. The patient unconsciously masks its manifestation, stereotyping a normal gait, when observed, so that it is not evident. The asymmetry observed above in the left limb is reflected in the tibialis anterior muscle activity, where there is an absence of biphasic activity. Muscle activity at this level is found to be spastic, with a prevalence to sustained dorsiflexion. The gastrocnemius presents an abnormal premature activation in the initial phase of foot stance in both limbs, which corroborates the asymmetries obtained in the kinematic measurements, see **Figure 6**. In the case of the left semitendinosus, there is a premature activity in the mid stance phase, related to the increase in flexion of the left knee in the same phase. This behavior was found in a particular way for the subject under study and reinforces the asymmetry of the gait towards the left side, which as a whole represents a reduced action of the hip abductors and a weak or deficient control of the trunk during the transfer of the body weight of that limb, which confirm the findings of previous studies [12].

5. Conclusion

With the study carried out, it was possible to obtain a comprehensive analysis of the gait of a subject after 12 years of THA. For the first time, quantitative information on gait in hip arthroplasty in the national context is supplemented, thus contributing to future research. The use of the method lays the foundations for the objective characterization of surgical and rehabilitation procedures in CTA through the study of pre-operative and post-operative cases, as well as, of a better design and planning of patients' lifestyles that positively influence the extension of hip prosthesis working cycles.

Conflicts of Interest

The authors declare that there is no conflict of interest.

References

[1] Stavrakis, A.I., SooHoo, N.F. and Lieberman, J.R. (2015) Total Hip Arthroplasty Has Similar Complication Rates to Unilateral Total Hip Arthroplasty. *The Journal of Arthroplasty*, **30**, 1211-1214. https://doi.org/10.1016/j.arth.2015.02.015

[2] Pagès, E., Iborra, J. and Cuxart, A. (2007) Artroplastia de Cadera. *Rehabilitación*, **41**, 280-289. https://doi.org/10.1016/S0048-7120(07)75531-7

[3] Jacho Ascayo, J.J. (2017) Tratamiento fisioterapéutico en artroplastia de cadera. http://repositorio.uigv.edu.pe/bitstream/handle/20.500.11818/1816/TRAB.SUF.PROF.%20JACHO%20ASCAYO%2C%20JESSICA%20JANET.pdf?sequence=2&isAllowed=y

[4] Petis, S., Howard, J., Lanting, B., Jones, I., Birmingham, T. and Vasarhelyi, E. (2018) Comparing the Anterior, Posterior and Lateral Approach: Gait Analysis in Total Hip Arthroplasty. *Canadian Journal of Surgery*, **61**, 50-57.

[5] Perron, M., Malouin, F., Moffet, H. and McFadyen, B.J. (2000) Three-Dimensional Gait Analysis in Women with a Total Hip Arthroplasty. *Clinical Biomechanics*, **15**, 504-515. https://doi.org/10.1016/S0268-0033(00)00002-4

[6] Colgan, G., Walsh, M., Bennett, D., Rice, J. and O'Brien, T. (2016) Gait Analysis and Hip Extensor Function Early Post Total Hip Replacement. *Journal of Orthopedics*, **13**, 171-176. https://doi.org/10.1016/j.jor.2016.03.005

[7] Yoo, J. ., Cha, Y.H., Kim, K.J., Kim, H.Y., Choy, W.S. and Hwang, S.C. (2019) Gait Analysis After Total Hip Arthroplasty Using Direct Anterior Approach Versus Anterolateral Approach: A Systematic Review and Meta-Analysis. *BMC Musculoskeletal Disorders*, **20**, 1-10. https://doi.org/10.1186/s12891-019-2450-2

[8] Miyazaki, S., Miyazaki, S., Tsuruta, K., Yoshinaga, S., Yamaguchi, Y., *et al.* (2022) Effect of Total Hip Arthroplasty on Improving Locomotive Syndrome in Hip Disease Patients: A Prospective Cohort Study Focused on Total Clinical Decision Limits Stage 3. *Journal of Orthopaedic Science*, **27**, 408-413. https://doi.org/10.1016/j.jos.2020.12.028

[9] Ninomiya, K., Takahira, N., Ikeda, T., Suzuki, K., Sato, R. and Hirakawa, K. (2022) Prevalence of Locomotive Syndrome in Japanese Patients More than 10 Years after Total Hip Arthroplasty: A Cross-Sectional Cohort Study. *Journal of Orthopaedic Science*, **27**, 176-180. https://doi.org/10.1016/j.jos.2020.11.023

[10] BTS (2022) BTS Bioengineering. https://www.btsbioengineering.com/

[11] Nankaku, M., Tsuboyama, T., Kakinoki, R., *et al.* (2007) Gait Analysis of Patients in Early Stages after Total Hip Arthroplasty: Effect of Lateral Trunk Displacement on Walking Efficiency. *Journal of Orthopaedic Science*, **12**, 550-554. https://doi.org/10.1007/s00776-007-1178-2

[12] Loizeau, J., Allard P., Duhaime, M. and Landjerit, B. (1995) Bilateral Gait Patterns in Subjects Fitted with a Total Hip Prosthesis. *Archives of Physical Medicine and Rehabilitation*, **76**, 552-557. https://doi.org/10.1016/S0003-9993(95)80510-9