TIME PARAMETERS DIFFERENCES BETWEEN NORMAL AND TOTAL HIP ARTHROPLASTY GAIT

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Abstract: *The gait analysis has been used in rehabilitation and clinical investigation. The objective of this work is to compare the duration of each event in normal and Total Hip Arthroplasty (THA) locomotion. 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 using two platforms of force. The frequency of these equipments was set in 60 Hz. The results presented in this work were obtained through the analysis of 28 normal adults and 9 elderly patients with one year of post-operative. In this paper will be presented results that have been used as a support for gait analysis in the clinical rehabilitation.*

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

1. Introduction

Human locomotion requires the integration of numerous physiological systems to sequence events necessary to accomplish efficient walking. Normal gait requires: stability to provide antigravity support of body weight, mobility to allow smooth motion as body segments pass through a series of positions and motor control to sequence multiple segments while transferring body weight from one limb to another. So, functional disease, trauma, degeneration, fatigue or pain introduces limitations requiring compensatory action. The resultant gait pattern is a mixture of deviations caused by the primary dysfunction as well as compensatory motion dictated by residual function.

Walking is one of the most common human physical activities. Evaluation of time and distance parameters during walking is helpful in assessing abnormal gait, to quantify improvement resulting from interventions, or to predict subsequent events such as falls. This evaluation is useful in several clinical situations such as: functional performance assessment after treatment or surgery such as hip and knee arthroplasty (Wall et al., 1996), fall risk assessment in elderly people (Maki, 1997) or selecting the appropriate assistive device.

Starting in the late 1950s with the pioneering work by John Charnley (Andriacchi and Hurwitz, 1997), the total hip arthroplasty is now an established orthopedic operation with high rate of success, based on clinical and radiographic criteria. However, the presence of progressive mechanical loosening has been noted (Perrin et al., 1985) and it is also necessary to access the functional status of total hip arthroplasty. Gait function is an objective measurement of the probable activity level and functional status of the patient. Several authors have reported improved measurable gait parameters, such as velocity and oxygen consumption, from one to four years post operation. Others showed decreases in cadence, step and time support.

Therefore, gait analysis can provide an objective evaluation of these devices, since it can detect subtle functional adaptation to implant design that cannot be obtained by other means (Hodge et al., 1991).

This work have been performed in Research Center of the Human Movement-CPMH/INTO-MS - Rio de Janeiro-Brazil and have been studied the following space-time parameters: support and swing times, weight acceptance and pre-swing phases, cadence, velocity, step, stride and step's width or base of support.

2. Definitions

The stride is used in this work as the minimum unit of the gait cycle and its period is equal to the time between two consecutive heel strikes of the same limb. The linear displacement of the limb during one cycle is the stride length while the distance of the heel strikes of different limbs is classified as step (Fig. 1).

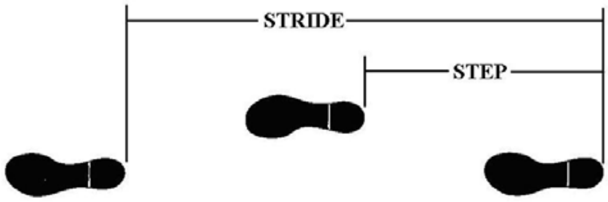

Figure 1. Stride and Step length

During one stride, the limb passes for two periods: stance and swing. In the stance period the limb is in contact with the ground while in the swing the limb is balancing to the future position. The support phase is divided in single (opened chain) and double support (closed chain). While the single support only one foot is in contact with the ground, in the double support two feet are in contact with the ground (Fig. 2).

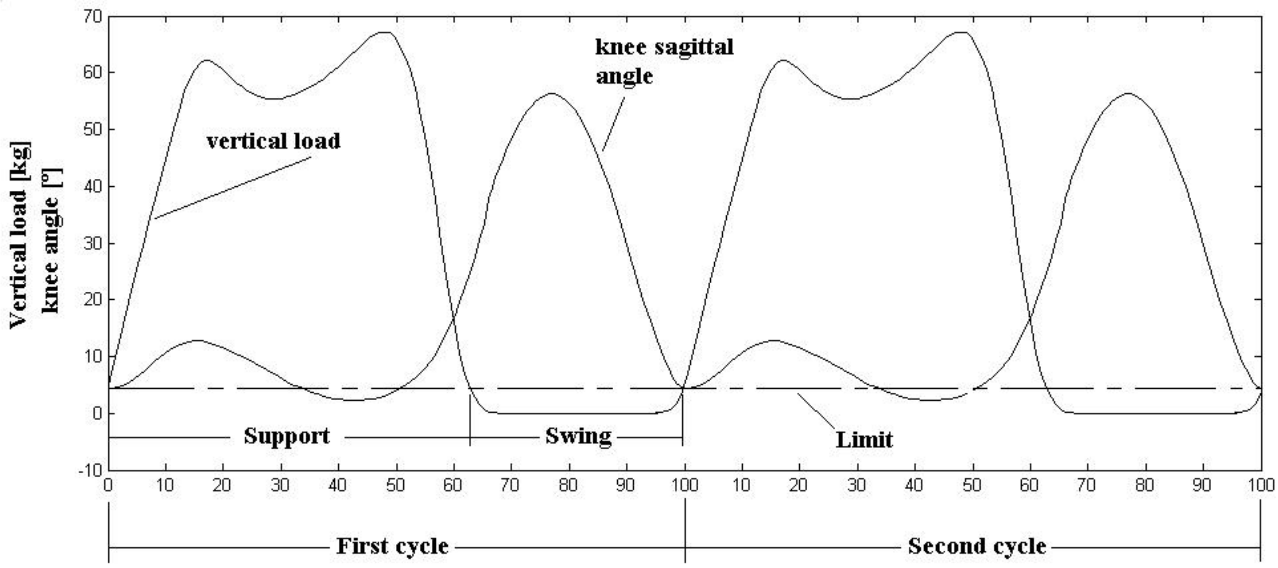

Figure 2. Stance and swing periods in percent of gait cycle

The stance period is divided in four phases: initial contact, loading response, mid stance and pre-swing. The initial contact and loading response formed the weight acceptance and the limb is in double support. In the mid stance the limb is in single support. The pre-swing phase establishes the beginning of the limb movement. The stance constitutes approximated 60% of the cycle.

The support can be defined as a period of time between limb contact, which in the normal case is named heel strike, and the toe off when the foot leaves the ground. In the other hand two force plates to establish these events were used (Fig. 3). So, the weight acceptance was defined as the period between the limb contact and the first maximum of the vertical force measurement by the platforms while the mid stance was adopted as period between the first and second maximum of this force. Consequently, the pre-swing was adopted as a period between the second maximum of vertical force and the end of support.

It is very important to observe that the knee flexes and absorb part of the ground reaction force. The forces line passes behind the knee joint and produces a flexion moment in this joint. Therefore the weight acceptance could be marked based in the first maximum of the vertical force associated with a flexion movement of the knee.

A similar event occurs in the pre-swing phase. In this phase the knee flexes to permit the stretch of soleus muscle for developing impulsive force. Therefore the pre-swing phase could be marked based in the second maximum of vertical force associated with a flex movement of the knee.

The Figure (3) illustrates these assumptions, with the vertical load plotted together with the knee angle, where the weight acceptance phase is represented by gray color, the mid stance phase is represented by blue color and the pre-swing phase is represented by orange color.

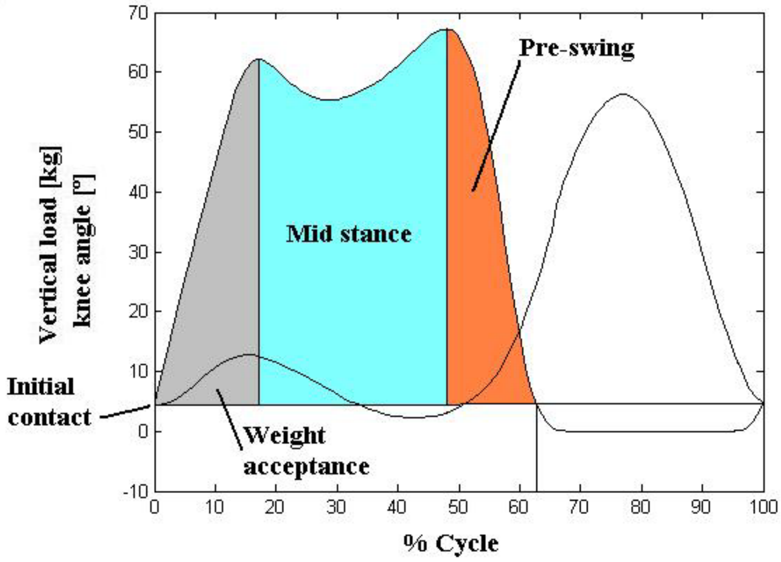

Figure 3. Weight acceptance, mid stance and pre-swing definitions

The last important definition is the width of the step or support base. It was defined as the lateral-medial distance among the centers of the ankles.

3. Materials and Equipaments

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. (4).

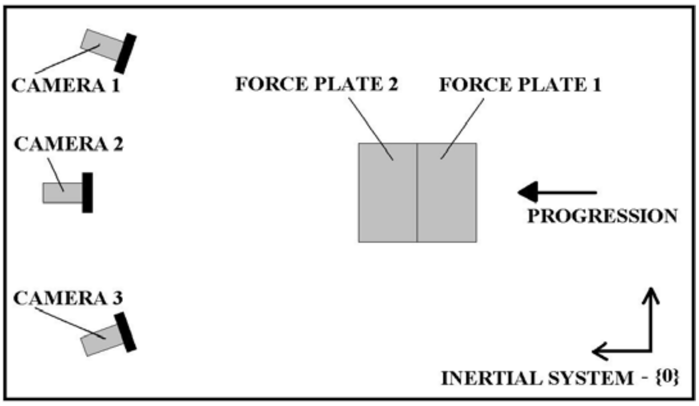

Figure 4. Walking way and equipments of the gait lab

The results presented in this work were obtained through the analysis of 28 normal young adults without history of musculoskeletal problems and 9 elderly patients with one year of post-operative of Total Hip Arthroplasty. The normal group of control is formed of 11 men and 17 women and has the following characteristics: 22.3 ± 2.2 years old, 1.69 ± 0.09 m of height and 66.5 ± 14.9 kg of weight. The THA group of control is formed of 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.

4. Experimental Protocol

The protocol of markers was defined in Raptopoulos et al. (2003) and the following anatomical points were employed: the medial areas 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 time parameter.

5. Results

In the Fig. (5) is presented the support and swing sub-phases of each group of control, where each phase or period was plotted in percent of cycle.

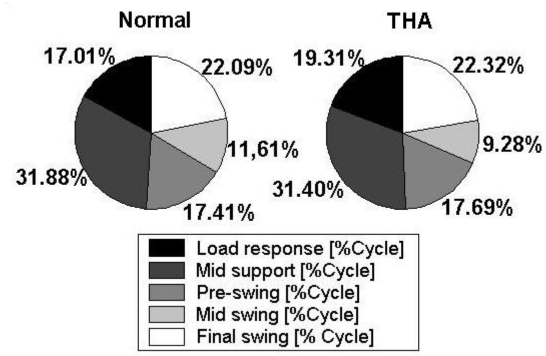

Figure 5. Phases of the gait cycle of normal and THA gait

The support and swing periods of each group of control are presented in the Fig. (6).

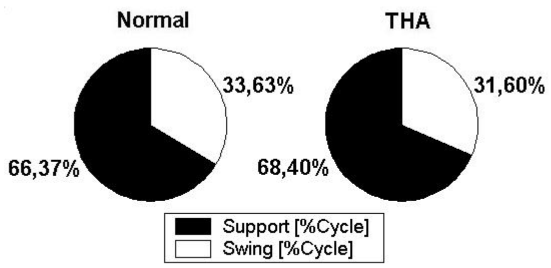

Figure 6. Stance and swing periods of normal and THA gait

Other important phases are the loading response, mid stance and pre-swing. The support period can be divided in these three phases as presented in the Fig. (7).

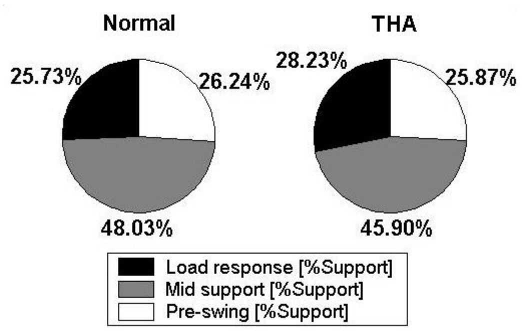

Figure 7. Stance phases of normal and THA gait

The Figure (8) shows the percent difference among the steps of each group of control, in relation to the stride length. The Figure (9) presents the step and stride length of these groups.

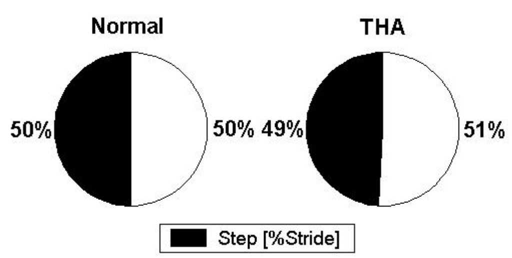

Figure 8. Step percent of stride of normal and THA gait.

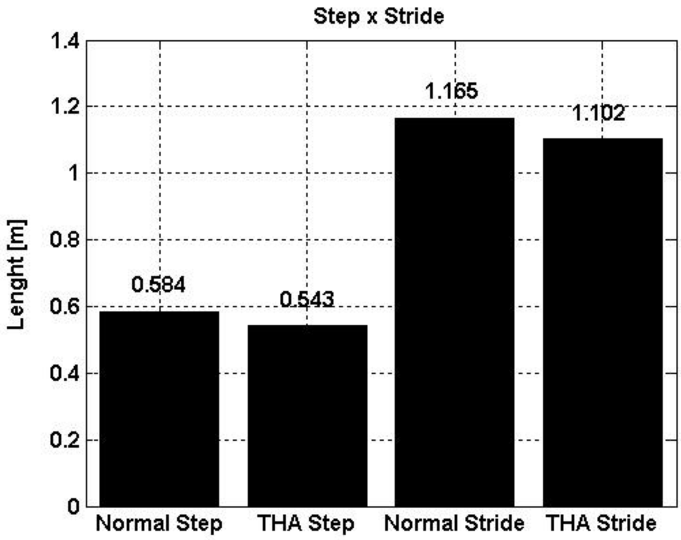

Figure 9. Comparison among natural and THA step and stride

The last three analyzed parameters are the base width, the velocity of progression and cadence. While the Figure (10) presents the base, the Fig. (11) and (12) present velocity and cadency of each group of control.

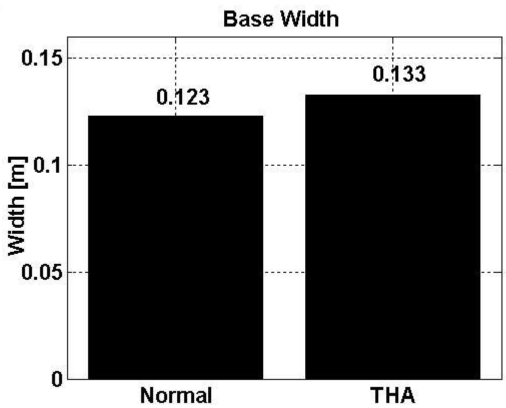

Figure 10. Comparison among natural and THA base width

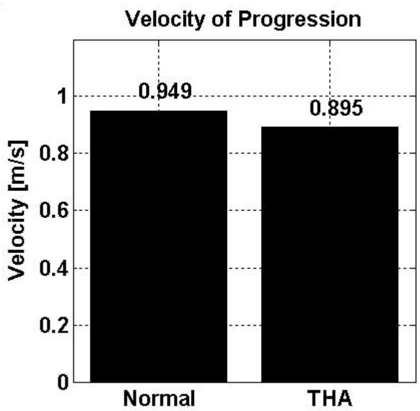

Figure 11. Comparison among natural and THA velocity

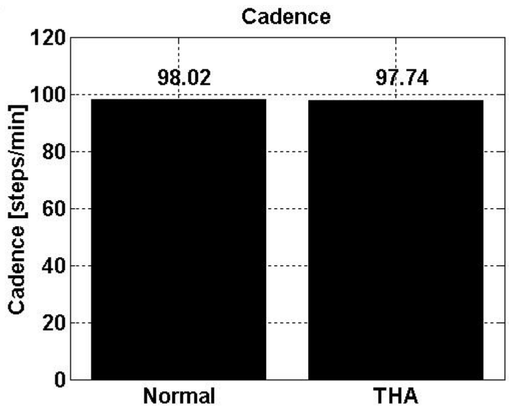

Figure 12. Comparison among natural and THA cadence

6. Discussion

No significant differences were found between the THA group and normal group. All subjects of the THA group had 1 year of pos-operative and passed to a specific rehabilitation program at the same period. As expected, the THA group presented near values to each parameter compared to the normal group. Table 1 shows the characteristics of time parameters of each group with mean and standard deviation.

Table 1. Characteristics of the subjects.

Characteristic	**Unit**	**Normal Group**		**THA Group**	
		Mean	**Standard deviation**	**Mean**	**Standard deviation**
Age	[years]	22.27	2.16	54.88	14.27
Mass	[kg]	66.500	14.888	73.706	16.891
Height	[m]	1.689	0.091	1.657	0.085
Cycle	[s]	1.241	0.127	1.241	0.126
Load response	[% cycle]	17.01	1.85	19.31	2.82
Mid support	[% cycle]	31.88	2.46	31.40	2.40
Pre-swing	[% cycle]	17.41	2.27	17.69	2.47
Mid swing	[% cycle]	11.61	4.97	9.28	6.43
Final swing	[% cycle]	22.09	2.48	22.32	3.22
Support phase	[% cycle]	66.37	2.48	68.40	3.22
Swing phase	[% cycle]	33.63	2.48	31.60	3.22
Stride	[m]	1.165	0.092	1.102	0.104
Step	[% stride]	50.00	4.55	49.00	2.81
Width of the base	[m]	0.123	0.034	0.133	0.041
Progression speed	[m/s]	0.949	0.116	0.895	0.125
Cadence	[steps/min]	98.021	9.508	97.74	9.457

An Anderson-Darling Test was applied to observe the hypothesis of a normal distribution. All of the characteristics have a normal distribution with Anderson-Darling Test's valor lesser than 1.321. A *T test* was applied in order to the null hypothesis that there are no differences between the groups (H0 = means are equals) with the alternative hypothesis that there are differences between the groups (H1 = means are not equals). A significance level of 5.0% was adopted. P-valor grater then 0.05 indicates that there are no differences between the groups. The test was applied for cycle, load response, mid support, pre-swing, support phase, swing phase, stride, step, cadence, progression speed and width of the base. Table 2 shows the results of the Anderson-Darling test and *T test* of each time parameters.

Some gait analysis studies (Murray et al., 1972; McGrouther, 1974; Murray et al., 1976) have suggested that completely normal function is not achieved following total hip arthroplasty in a period less than 6 months after surgery. Others studies (Hodge et al., 1987 e 1989) demonstrated that the kinematics parameters returned at near normal values at 1½ years after surgery.

The aim to the analysis of patient following total hip arthroplasty is to understand that the patients adapt to stimuli such as pain, instability or muscle weakness. The adaptation often appears before significant clinical problems become apparent.

Table 2. Anderson-Darling Test and T Test's results

Characteristic	Anderson-Darling Test (A = 1.321)		T Test (α = 0.05)		Final Result
	A	Hypothesis	P-Valor	Hypothesis	
Cycle	1.1717	Normal	0.99353	H0	Means are equals
Load response	0.8104	Normal	0.99353	H0	Means are equals
Mid support	0.38073	Normal	0.9969	H0	Means are equals
Pre-swing	0.59521	Normal	0.9906	H0	Means are equals
Support phase	0.21602	Normal	0.99214	H0	Means are equals
Swing phase	0.47687	Normal	0.99991	H0	Means are equals
Stride	0.25611	Normal	0.98398	H0	Means are equals
Step	0.17725	Normal	0.80505	H0	Means are equals
Width of the base	0.6305	Normal	0.98437	H0	Means are equals
Progression speed	0.18694	Normal	0.98488	H0	Means are equals
Cadence	0.70075	Normal	0.99353	H0	Means are equals

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 analyzed more subjects of each group, mainly of the THA group of control.

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