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Analysis of Torque and Power supported by the Hip during a change of Sitting position to Standing and Walking Cycle

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***Abstract*—In the present study we analyze the speed, acceleration, torque, boiler power during a complete phase of human walking and of the change of state: from sitting position to standing position. As a part of the experimentation methodology, we use artificial vision and with this we capture the points located in: hip, knee and ankle, these are states join by segments, to finally obtain the variation of the angle produced by each segment relative to the vertical.**

***Index Terms*—Artificial Vision, Force, Momentum, Power, Progress Cycle, Standing, Seating Systems, Torque, Speed.**

I. INTRODUCTION

The hip is one of the fundamental parts of the human body, offering the great benefits of mobility and primarily, support to the transmission of loads. The femoral head, which is part of the same thing, constitute two-thirds and it is covered with a cartilage which tapers towards the subcapital groove, at the junction of the head with the femoral neck. [23]

This articulation presents the possibility of mobility in all directions, which is made by moving around the center of the femoral head, by sliding between the articular surfaces [8], with a tangential direction with the contact of the surface.[12]

As mentioned above the hip has a wide range movements in different planes [9], [3], each with different angles, in the sagittal plane it is 140 degrees, in the extension it is 15 degrees. In the frontal plane an abduction movement of 30 degrees and other adduction movement that reaches 25 degrees [23]. In the horizontal plane, talking about the external rotation, the angular variation goes between 60 and 90 degrees, while the inner rotation goes between 30 to 60 degrees, all this in case of bending or extending [12].

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II. TORQUE APPLIED BY THE HIP

For determination of the torques, forces and other objects for this study, we had the following function, which represents the torque applied to a lever, as explained in the free body diagram of Figure 1, and can be expressed as follows [18]:

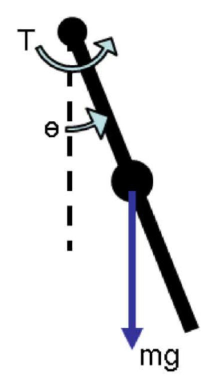

Figure 1. Diagram of torque applied to a lever [7], [18]

$$T = \ddot{\theta} * I + m * g * l * sin(\beta) \quad (1)$$

Where:

- $\ddot{\theta}$ =Function of the angular acceleration produced by the hip in the gait cycle.
- I =Moment of inertia produced in the leg from the hip joint to the knee.
- m =Mass of the leg from the hip joint to the knee.
- g =Gravitational constant.
- l =Length of the leg from the hip joint to the knee.
- $sin(\beta)$ =Angle produced by the vertical respect to the segment of the leg between the join with the hip and the knee.

III. ANALYSIS OF PATHS, SPEED, TORQUE AND POWER IN THE CHANGE FROM A SSEATED POSITION TO A STANDING POSITION

In the developing of the experiment, we capture points located in the hip, knee and ankle, by using a camera positioned as indicated in Figure 2. It should be noted that the viewing angle of the camera to obtain the data, doesn't affect in any way the obtain data. The obtained angles for each experiment do not depend in the virtually created segments for this analysis, so the view factor of the camera has no influence capturing the data on the experiment.

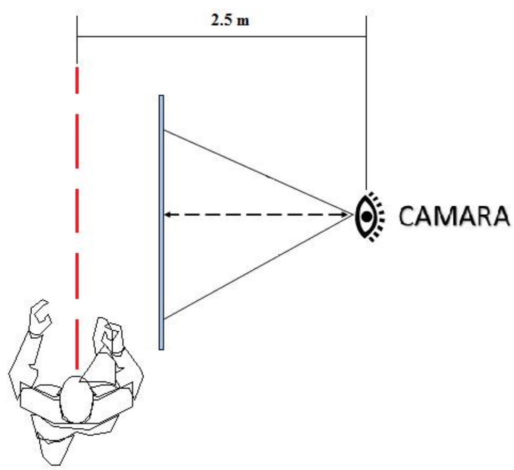

Figure 2. Camera focus and position of lower extremities for experimentation and data collection at a height of 1m with respect to floor.

With the captured data the trajectories made by hip and leg are modeled, fundamental for getting up, an d for this we used a point diagram, joined by sections (see Figure 3 and 4), which vary with the change of position in the change cycle from sitting position to a standing position, measuring in real time the variation of the angles relative to the horizontal.

Figura 3. Points for data acquisition and processing paths in changing sitting position to standing

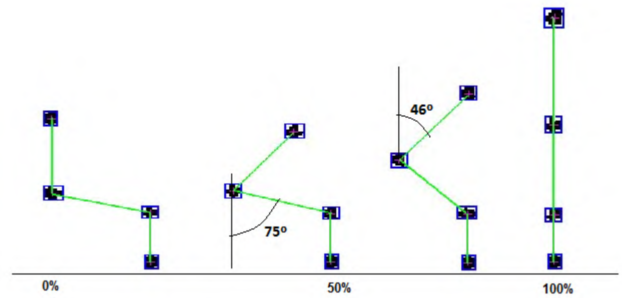

Figure 4. Drawn segments into the cycle of change from sitting position to a standing position, for real-time measurement of the trajectories performed by the hip and leg.

Through a process of interpolation of the obtained points, by the method of sines summation we acquire equations of displacement of the hip and the leg of the cycle mentioned in the previous paragraph.

$$\theta_i = a1*sin(b1*x+c1)+a2*sin(b2*x+c2)+a3*sin(b3*x+c3)-k \quad (2)$$

Where the coefficients of the approximation for the function which describes the angular displacement of the hip are:

- $a1 = 36.59$, $b1 = 0.03336$, $c1 = 2.909$,$a2 = 2.516$, $b2 = 0.1898$, $c2 = -0.3746$, $a3 = 5.848$, $b3 = 0.1063$, $c3 = -2.07$
- $k = 2.5$ constant of setting vertical scroll.

As the hip is necessary to comply with the standing process of a person, the leg also serves as body support in this cycle and produces a displacement which has been analyzed using the Equation 2.

Where the coefficients of the approximation for this case, where the angular displacement of the leg will be described are:

- $a1 = 274$, $b1 = 0.001481$, $c1 = 2.933$, $a2 = 22.67$, $b2 = 0.04465$, $c2 = 1.001$, $a3 = 0.879$, $b3 = 0.1726$, $c3 = -2.351$.
- $k = 0$ Constant of vertical scrolling setting.

Given these results the Figures 5 and 6, represent functions of displacement for both the hip and leg for the analysis.

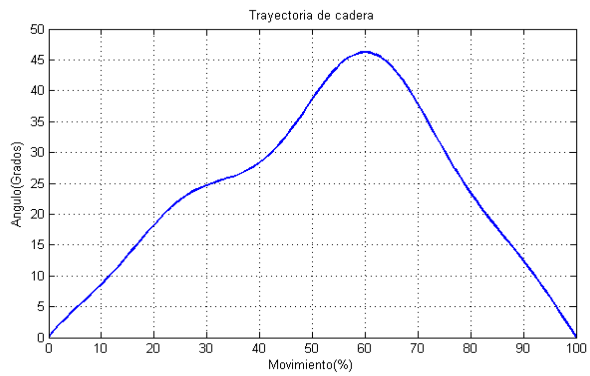

Figure 5. Hip displacement in the change of state, from sitting position to a standing position

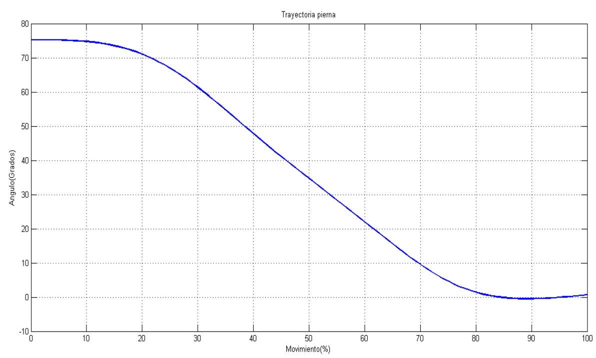

Figure 6. Displacement of the leg in the change of state, from sitting position to a standing position

Equation 2, for the hip and leg, it allows the obtaining of speed and acceleration results that the hip performs in the status change, from sitting position to a standing position, for this we need to apply the following mathematical operations:

$$\dot{\theta} = \frac{\partial\left(\theta\right)}{\partial t} \tag{3}$$

$$\ddot{\theta} = \frac{\partial\left[\partial\left(\theta\right)\right]}{\partial\left(\partial t\right)} \tag{4}$$

With this background velocity and acceleration of the hip for the changing cycle, from sitting position to a standing position, functions are presented. For this Figures 7, 8 are shown.

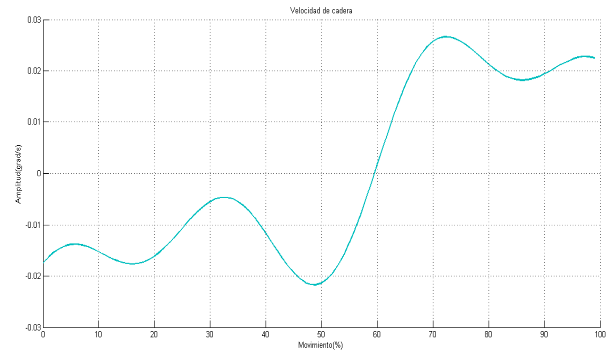

Figure 7. Hip velocity in the change from sitting position to a standing position

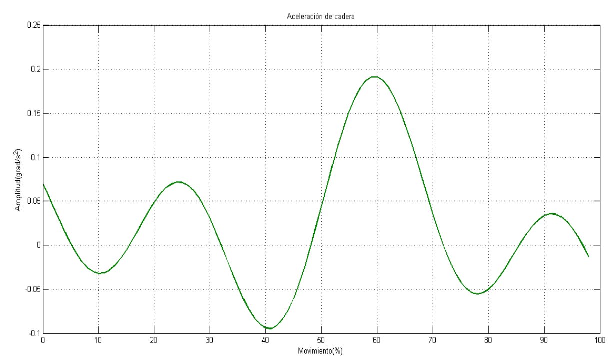

Figure 8. Acceleration of the hip in the change from sitting position to a standing position

In Figures 9, 10, we observe the obtained results for the leg.

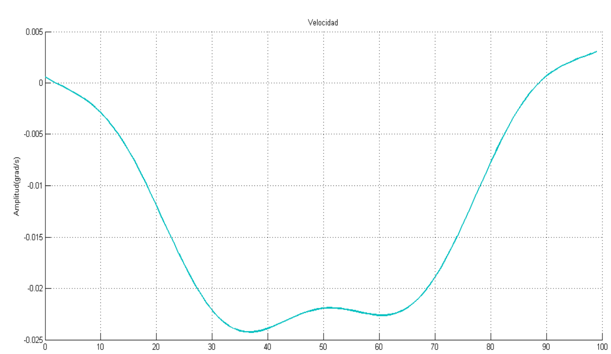

Figure 9. Leg speed in the change from sitting position to a standing position

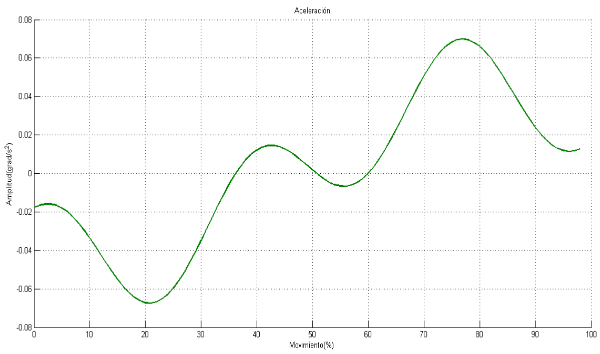

Figure 10. Acceleration of the leg in the change from sitting position to a standing position

With Equations 3 y 4 we can be applied the Equation 1, with this the torque according to the displacements made by both, leg and hip, as shown in Figures 11, 12.

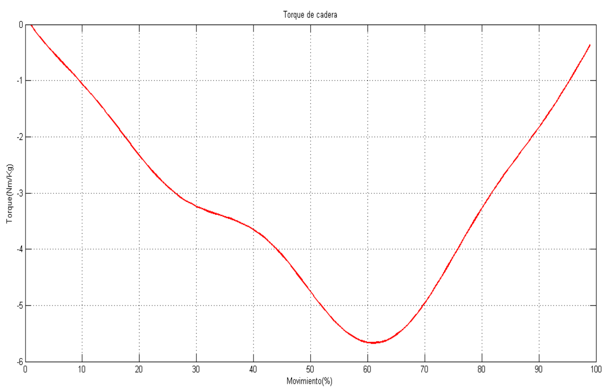

Figure 11. Torque applied by the hip in the change from sitting position to a standing position

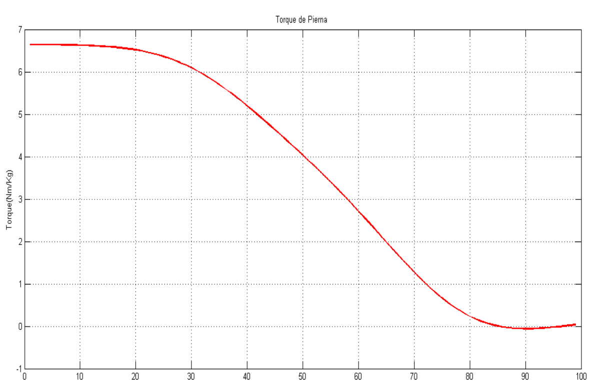

Figure 12. Torque applied by the leg in the change from sitting position to a standing position

With the data obtained from the trajectories and the torque applied to the hip, we obtain the power that this develops, and its function is shown in Figure 13, using Equation 5.

$$P = T \cdot \omega \tag{5}$$

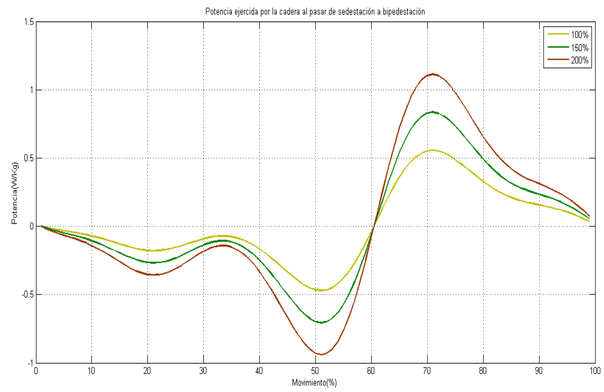

Figure 13. Effect of increasing the speed, in the power applied to the hip to change from sitting position to a standing position

IV. ANALYSIS OF PATHS, SPEED, TORQUE AND POWER IN WALKING CYCLE

Firstly, for the experimentation of the walking cycle and its analysis, we realized a point diagram or natural junctures of the body such us: hip, knee and ankle, in which landmarks will be placed for the elaboration of the model.

The modeling of the march is performed taking angle values relative to the vertical, by calculating the slope of linear lines between specific points of the lower limbs, as shown in Figure 14, with a capture process data in real time.

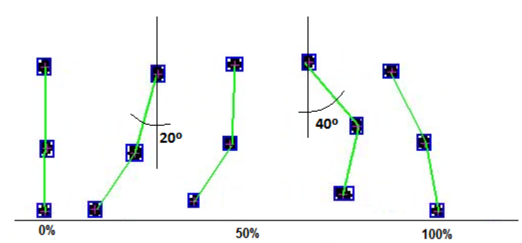

Figure 14. Drawn segments for the simulation of human walking

Figure 15, the points taken for the data capture process in the walking cycle is shown below:

Figure 15. Points for data acquisition and processing paths in the walking cycle

With these data, an interpolation process is applied by the sum of sines, the result of this is the function of the Figure 16.

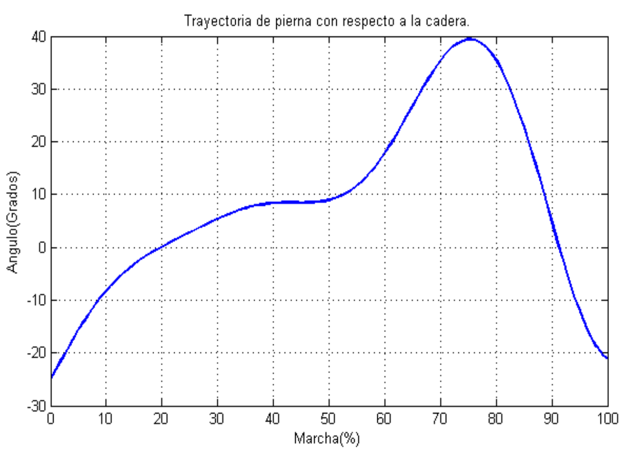

Figure 16. Path of the hip in the walking cycle

Thus, the Equation that represents the Figure 16, would be: Equation 2.

Where the coefficients of the approximation for the function that describes the angular displacement of the hip are:

- $a1 = 324.6$, $b1 = 0.138$, $c1 = -7.643$, $a2 = 23.42$, $b2 = 0.04046$, $c2 = -1.096$, $a3 = 318.3$, $b3 = 0.1391$, $c3 = -4.533$
- $k = 0$ Constant of the vertical scrolling setting.

This enables to obtain results of speed and acceleration that the hip does in the walking cycle this requires the following mathematical operations to be done, already shown in the Equations 3 y 4.

Where θ represents the Equation 2 and allows us to obtain the functions shown in Figures 17, 18.

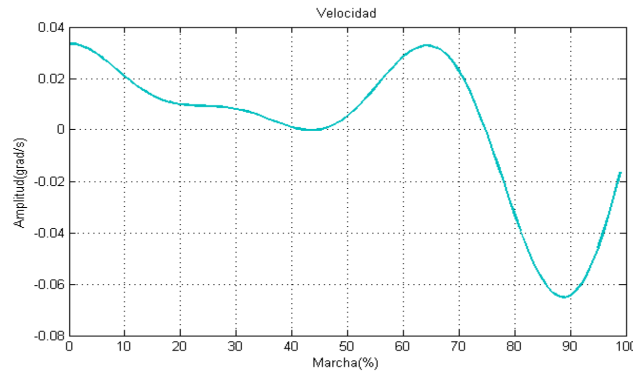

Figure 17. Speed produced by the hip in the walking cycle

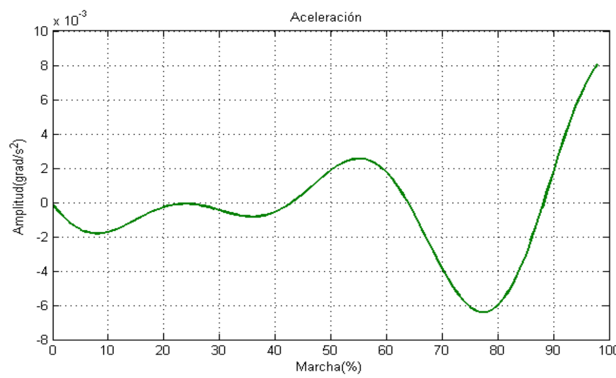

Figure 18. Acceleration produced by the hip in the walking cycle

Using Equation 1 and the obtained trajectories by the hip at the time of the walking cycle, the torque function is obtained by this limb in the Figure 19.

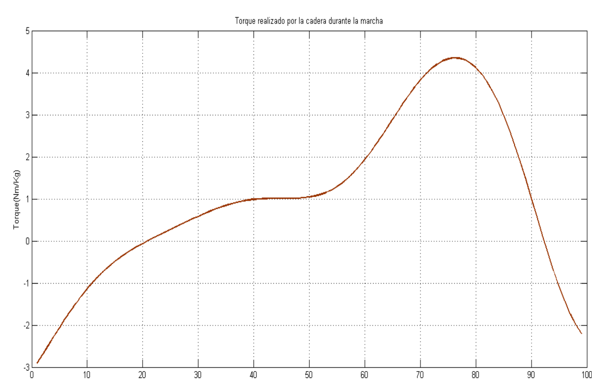

Figure 19. Role of the torque applied by the hip during the walking cycle

With the data obtained from the trajectories and the applied torque to the leg, we get the power that is the same, with the function introduced is presented in Figure 20, using Equation 5.

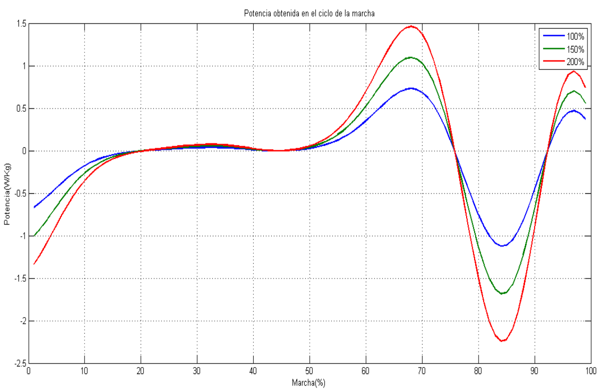

Figure 20. Effect of increasing the speed, in the power applied to the hip for the walking cycle

V. CONCLUSIONS

The document shows the experimentation of the walking cycle and the change from sitting position to a standing position; with this ´process we formulate the functions which describe the movements of the hip for the mentioned cycles and the changes of position.

The analysis of the changes of position are set in a sagittal plane, which involves a cinematic analysis in two dimensions, all this connects the whole analysis to the development of the research.

The capture of the data through the artificial vision allows the easy processing of paths made by the lower body segments.

In order to obtain a lower power in each cycle it's necessary to vary the speed with which these are carried out, in the experimental data, we obtained data as Figures 13 and 20; in which it's show the change in the power developed by the hip with speeds of 100, 150 and 200 percent more than the one developed in the experiment and found in Figures 7 and 18, both to the walking cycle and the change from the sitting position to a standing position.

To make the change from the sitting position to a standing position, one person needs a greater torque to accomplish with this cycle respect to the walking cycle as shown in Figures 11 and 19.

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