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# DETERMINATION OF NORMAL CYCLE GAIT PARAMETERS

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**Abstract:** This paper treats some theoretical and experimental aspects about normal human gait. For the experimental part we used a human subject (23 years old) with a body weight of 59.9 kg, which was subjected to some tests to determine the human gait parameters in normal conditions before and after effort. As experimental devices we used a medical bicycle, a Kistler plate, a signal amplifier, two acquisitions boards for analogue and digital signals and a data acquisition system (laptop). The results, reaction forces and moments for all three directions, have been graphly displayed.

**Key words:** effort, gait parameters, Kistler plate, moments, reaction forces

## 1. General aspects of normal cycle gait

The gait cycle is the period of time between any two identical events in the walking cycle. Any event could be selected as the onset of the gait cycle because the various events follow each other continuously and smoothly. Initial contact, however, generally has been selected as the starting and completing event. By contrast, the gait stride is the distance from initial contact of one foot to the following initial contact of the same foot. Each gait cycle is divided into two periods, **stance** and **swing**. A full gait cycle is described as the undertaking of both stance and swing phases by one limb [1][2].

**Stance** is the time when the foot is in contact with the ground, constituting 62 percent of the gait cycle (figure 1). This phase is broken down into three distinct phases [1][2][3]:

- ***Contact*** - is the cushioning phase of the gait cycle. At this time the knee flexes immediately prior to the foot hitting the ground and the foot pronates or rolls in. The beginning of the contact phase of gait is signaled by the instance of heel strike. The end of the contact period is signaled by the instant the forefoot makes contact. This event is called foot flat and it marks the beginning of the mid stance phase of stance. The contact period lasts for about 25% of the total time the foot is in contact with the ground;
- ***Mid stance*** - is the time when the foot and leg provide a stable platform for the body weight to pass over. If the foot is still pronating at this time there is too much movement and instability. During mid stance the other foot is in swing phase and so all the body weight is born on the stance limb alone. This means that mid stance is a time when lower limb is particularly susceptible to injury. Mid stance is also the longest phase of the stance period and it lasts approximately 50% of the total stance period.
- ***Propulsion*** - is the final stage of the stance phase of gait. Propulsion begins immediately as the heel lifts. As the big toe dorsi flexes the windlass mechanism comes into play, tightening the plantarfascia and helping to raise the arch of the foot. The foot should be supinated during propulsion allowing the bones of the mid foot to brace against each other and producing a rigid structure capable of propelling the body weight forwards.

**Swing** denotes the time when the foot is in the air, constituting the remaining 38 percent of the gait cycle (figure 1). The swing phase begins when the foot is lifted from the floor until the heel is placed down. While walking the thorax rotates in clockwise and counterclockwise directions opposite the pelvic rotations. Some people display more rotation of the thorax, while others display more rotation of the pelvis. With each step the pelvis drops a few degrees on the side of the non-weightbearing, or swinging, leg. While the leg is swinging, the hip abductors of the weightbearing leg contract in order to prevent the pelvis from falling excessively on the unsupported side.

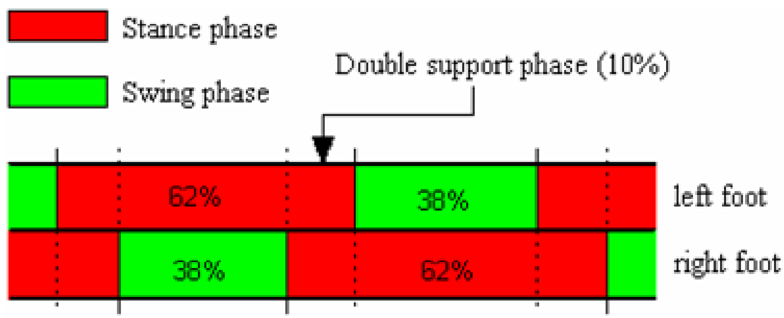


***Figure 1 Gait cycle divided into two periods, stance and swing***

This swing phase is broken down into four distinct phases [2][3][5]:

- ***Preswing*** – begins with the initial contact of the blue foot and ends with red toe-off. During preswing, the ankle moves rapidly from its dorsiflexion position at terminal stance to 20 degrees of plantarflexion. Although the ankle reaches its angular peak of plantarflexion during this period, actual plantarflexor activity is decreased in intensity, as the limb is unloaded. In late preswing, the vertical force is diminished, and the plantarflexors are quiescent.
- ***Initial swing*** - begins when the foot is lifted from the floor and ends when the swinging foot is opposite the stance foot. The initial one-third of the swing period, from the 62- to 75-percent periods of the gait cycle, is spent in initial swing. It begins the moment the foot leaves the ground and continues until maximum knee flexion occurs, when the swinging extremity is directly under the body and directly opposite the stance limb.
- ***Midswing*** - continues from the end point of the initial swing and continues until the swinging limb is in front of the body and the tibia is vertical. The knee is allowed to extend in response to gravity while the ankle continues dorsiflexion to neutral. The blue leg is in late mid-stance.
- ***Terminal swing*** - begins when the tibia is vertical and ends when the foot touches the floor. Limb advancement is completed by knee extension.

## 2. Equipment description

To determine the normal cycle gait parameters, in case of a subject with a body weight of 59.9 kg, in normal condition before and after effort, we used an equipment compound from a force plate by Kistler, a signal amplifier, two acquisition boards (for analogue and digital signals) and a data acquisition system (laptop) (figure 2).

The force plate is equipped with four force sensors (piezoelectric sensors), each sensor executes a distinct measurement. The final signal, which is transmitted to the amplifier, represents the resultant measurement effectuated by all four sensors. The resultant component |R| represents the vector quantity included between all three orthogonal components, X, Y, Z. The resultant value is given as by this relation [4]:

$$|R| = \sqrt{X^2 + Y^2 + Z^2} \quad (1)$$

The force plate measures in real time the coordinates of torsor: the three components of the plate reaction forces ($F_x$, $F_Y$, $F_z$) and also the three components of the moment ($M_x$, $M_Y$, $M_z$).

The calibration of the force plate was made before starting the measurements by using a calibration weight of 10 kg, and the smoothness of the surface was verified using a balance level.

For Kistler plate t here are two coordinates systems. The first one is the Kistler System, which is oriented in the way that the forces are applied to the plate. The second system is the International System in Biomechanics (ISB). This is a reaction system, which means that the system represents the direction of the reaction forces. For this experiment we have chose as reference system the Kistler System.

Under the external force induced by the subject, the piezoelectric sensors deform themselves transforming the mechanical action into the electrical signal. This signal, initial in milivolts, is received and amplified by the signal amplifier. The amplifier has the roll to transform the output data of the pressure sensors into the tension standard signals (tension between ± 1V and ± 10 V with low impedance), to effectuate the compensation of the sensors characteristics and to limit the frequency to the exact domain.

For the conversion of the analogue/digital signals we used two acquisition boards, respectively PC CARD DAS 16/16 and PC CARD D24/CTR3.

Minimum necessary to effectuate all the dynamic and static measurements are two channels for impute and one output channel. The analogue output channel is utilized to generate the excitation signal, and the impute channels to measure the real excitatory signal.

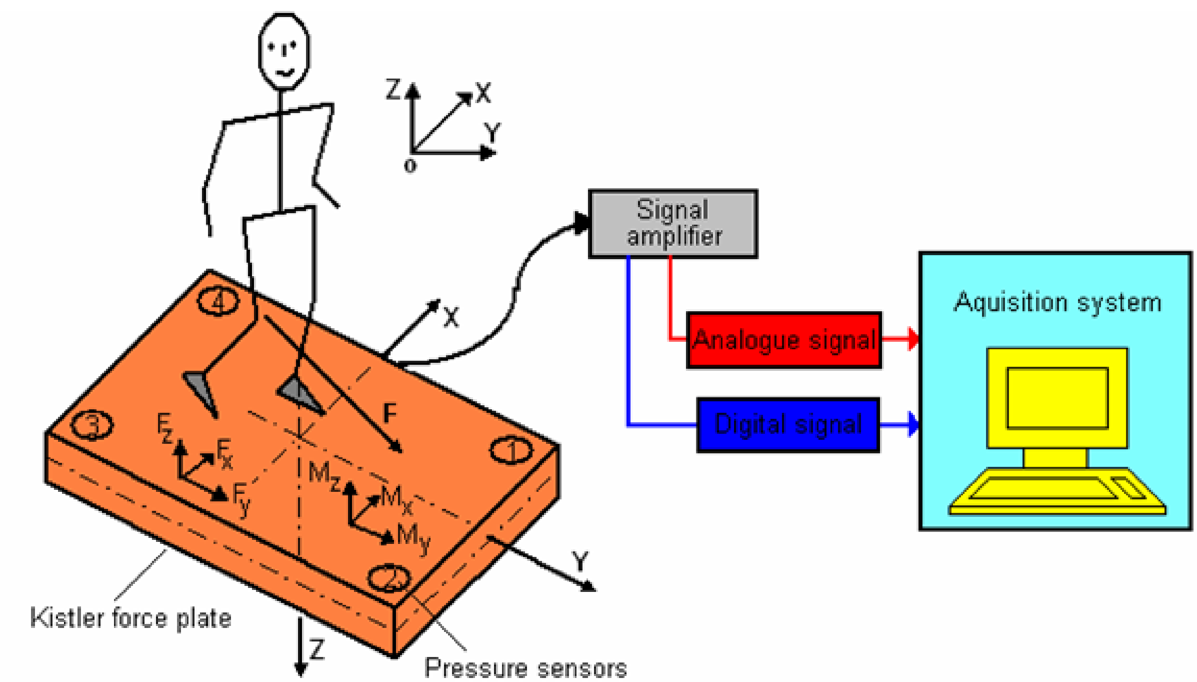


*Fig. 2 The installation used for determination of human gait parameters.*

## 3. Experiment developments and the results presentation

The proposed solution is based on the determination of the human cycle gait parameters (the reaction forces $F_x$, $F_Y$, $F_z$ and moments $M_x$, $M_Y$, $M_z$ for all three directions) in normal conditions before and after effort by using the equipment described before. To realize the experiment we used a 23 years old subject without neuromotor disabilities with a body weight of 59.9 kg. In the table 1 are written some of the physiological parameters of the subject, before and after effort.

In the first stage (before inducing the effort), the subject was subjected for a number of three tests for normal cycle gait (figure 3. a), and the concluding results of the reaction forces and the moments are written in the table 1, respectively graphly displayed (figure 4, 5). In the second stage, a medical bicycle induced the effort state of the subject by pedaling with an average speed of 23 km/h for a period of time of 15 minutes (figure 3. b). Then, as in the first stage, the subject was subjected for a number of three tests and the results are written in the table 1, respectively graphly displayed (figure 6, 7).

The registration time of the measurements experiment is 10 seconds with a work frequency of 250 Hz.

a) b)

***Fig. 3 a) Picture with the subject walking on the force plate; b) picture with subject inducing the effort by pedaling.***

***Table 1 Physiological parameters and gait parameters before and after effort.***

| | | | | | | |
|---|---|---|---|---|---|---|
| Age: 23 years | | | | | | |
| **Physiological parameters** | | | | | | |
| | | | ***Before effort*** | | ***After effort*** | |
| Arterial pressure [mmHg] | | | 10,2/6.1 | | 10.1/7.0 | |
| Pulse [bits/min] | | | 71 | | 92 | |
| Temperature [°C] | | | 36.7 | | 36.2 | |
| Weight [kg] | | | 59.9 | | 59.7 | |
| Height [m] | | | 1.75 | | 1.75 | |
| **Gait parameters** | | | | | | |
| | | | ***Before effort*** | | ***After effort*** | |
| | | | Min. | Max. | Min. | Max. |
| Reaction force | Right foot | $F_x$ [N] | -39.361744 | 61.725021 | -36.907970 | 57.456692 |
| | | $F_y$ [N] | -62.566963 | 72.804283 | -47.302929 | 81.613007 |
| | | $F_z$ [N] | 26.298895 | 669.320618 | 25.083666 | 700.209412 |
| Moment | Left foot | $M_x$ [Nm] | -137.379440 | 116.018501 | -139.428070 | 105.750114 |
| | | $M_y$ [Nm] | -60.295040 | 55.478466 | -64.076019 | 52.825680 |
| | | $M_z$ [Nm] | -14.505586 | 6.149766 | -14.495054 | 7.350346 |

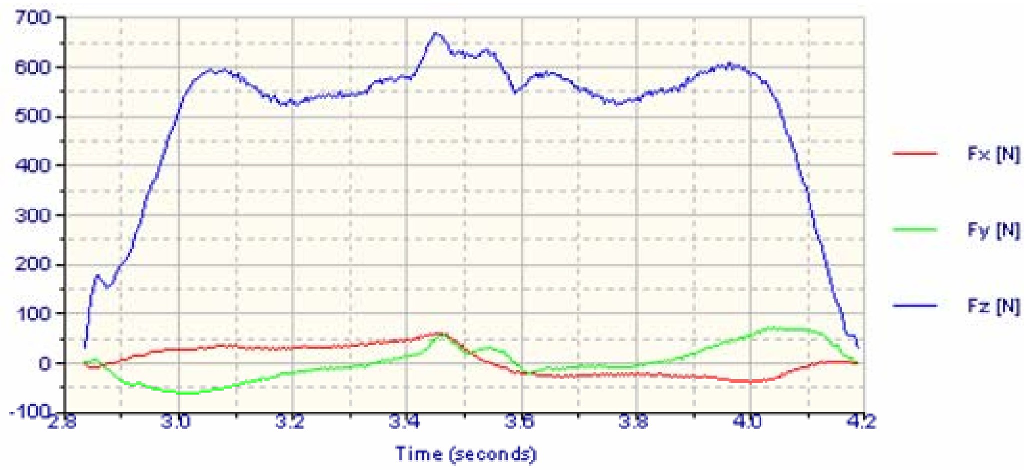


*Fig. 4 The diagram of the reaction forces in rapport to the contact time of the right foot with the force late in case of normal gait before effort.*

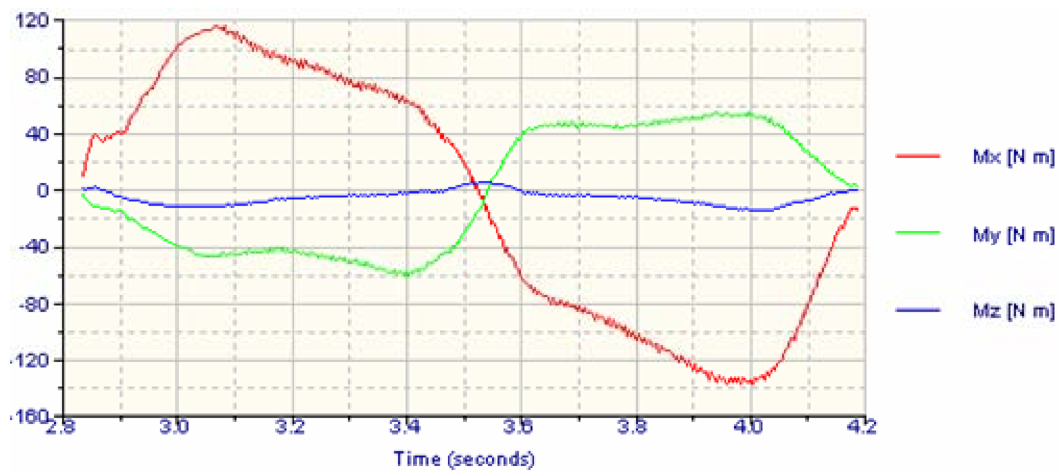


*Fig. 5 The diagram of the moments in rapport to the contact time of the right foot with the force late in case of normal gait before effort.*

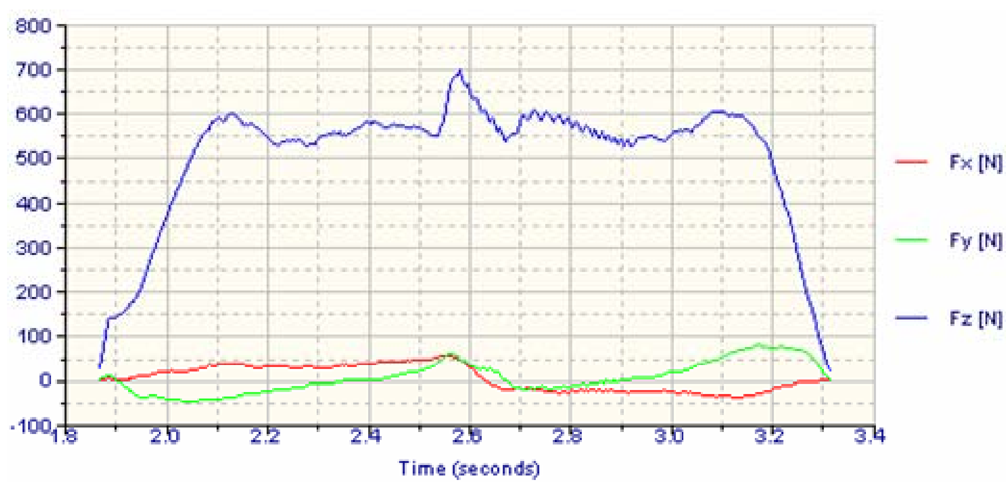


*Fig. 6 The diagram of the reaction forces in rapport to the contact time of the right foot with the force late in case of normal gait after effort.*

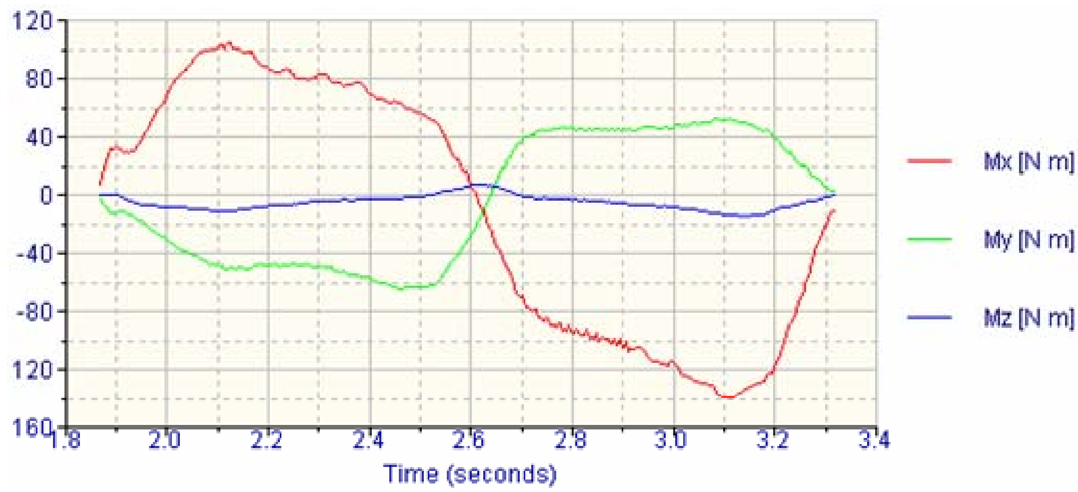


***Fig. 7 The diagram of the moments in rapport to the contact time of the right foot with the force late in case of normal gait after effort.***

## 4. Conclusions

Considering of the temperature diminution, from 36,7→36,2 °C, we can assume that, during effort, the human organism try to cool down by eliminating the exudation which trend to decries the surface temperature.

Also we can see some changes in reaction force values. Those, in case of Y and Z forces, there is a growth for registered values after effort. This can be explained by the increasing of the lactic acid from muscles, which leads to a contraction extension. Those, during the foot attack to the force plate, the subject trend to have a clamp walk.

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