Human Gait Analyzed by Complex and Interconnected System

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Abstract: - This paper presents the activities of our team in order to establish a configuration for biomechanical studies and to evaluate the human gait, for different persons and different environmental conditions. We also presented a methodology for recording and analyzing the information from a force plate used to give the values of forces and moments during the walking process. For that we used a complex computerized system with a high-speed video cam, an electro-medical apparatus set and a force plate with amplified signal. In the final part of the paper we presented the results and conclusions of these analyses.

Key Words: - human gait, force plate, motion.

1 Introduction

Using nonlinear data processing techniques and information recorded from different electro-medical apparatus it is possible to understand and to study complex processes like human walking.
Also, human locomotion is known to be a voluntary process, but it is also regulated through a network of neurons called a central pattern generator (CPG), capable of producing a syncopated output. The early nonlinear dynamical models of CPG's for gait assumed that a single nonlinear oscillator is used for each limb participating in the locomotion process. Human gait is a periodic motion form, especially when the subject walks laterally; hence it can predict human movement in a gait cycle, with periodicity of each leg moving. Some researchers consider human gait as a total walking cycle-the action of walking can be thought of as a periodic signal. Because each human body has a unique and special behavior, when they are walking, people move their torso, arms, and legs in a unique and personal way. Hence the rhythm of a gait should be different among individuals.

Fig.1. The steps sequence of a normal walking

This way, walking consists of a sequence of steps. These steps may be partitioned into two phases: a stance phase and a swing phase. The stance phase is initiated when a foot strikes the ground and ends when it is lifted. The swing phase is initiated when the foot is lifted and ends when it strikes the ground again. The time to complete each phase varies with the stepping speed. A stride-interval is the length of time from the start of one stance phase to the start of the next stance phase.
In different studies the pattern of the gait motion is assumed to be approximately sinusoidal curve of moving.
In kinematic analysis, however, the human gait is usually characterized by the joint angles between body segments and their relationships to the events of the gait cycle. For that, all gait analysis problems are the acquisition of information for an individual's gait and the possibility to introduce them into a general structure.
In many gait-data collection systems, there are some markers attached to the subject to facilitate the measurement of the required information, or other equipments in or not in contact with the human body, or computer vision techniques that can be adopted as a means of gait-data retrieval.
Since gait can be observed at a distance, gait recognition has advantages for example in surveillance system recognition or in biometric measurements
Also, because we have a very complex organisms living in a very complex environment, we need, for a compact analyzis structure, to know or to estimate how the environment influences an individual's health even though these actions are very hard to be determined.
Different factors affect individuals in different ways

and we can only understand the interactions between environmental factors and our health in terms of risk.
An important and major factor affecting human body stability and direction of walking is the support basis size; the forces and moments developed in the contact between legs and background are necessary to be analyzed especially at the moment of external factors action or when the person has some important disabilities or loco-motor trauma. All these information's can be collected and analyzed to establish the methodologies to evaluate the importance and size of disabilities or the impact of the environmental factors on the human behavior.
Different pathological factors affect a body's stability or walking behavior and could be estimated in the process of analyzis; but there are also different mechanical or environmental factors, like light, sound, temperature, vibrations or noises which can affect the entire human body's stability and walking in interconnected influences. All these aspects are very important in the process of understanding and correctly establishing the level of the human effort capacity necessary for a good health and life.

2. Developing the experimental setup

The experimental setup proposed by this paper is presented in fig.2.

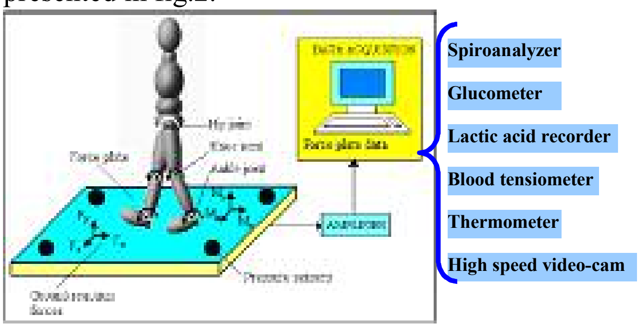

Fig.2. Experimental setup to record the walking and stability parameters of the human body using a Kistler force plate and electro-medical apparatus

Current gait analysis techniques used at this moment can be divided into three categories depending on the type of used device: wearable devices, walking on devices and visual gait analysis tools and techniques.
In our studies we set an interconnected structure using two techniques based on the gait visual recording tools and walking on devices
To record the forces and moments developed from 3 directions in walking and stability of the human body we use a **Kistler force plate** with 4 (four) piezoelectric sensors to measure these parameters of walking.
This force plate is equipped with an amplifier with 12 channels and supplementary, we can also use other 2 (two) similar force plates in the same amplifier and same time to obtain a longer distance of walking.
The specialized software for recording and managing the data is also available.
For that a very good and performing computer is necessary to be used because there are many and large recordings of the response signals from the acquisition system and also images (movies) from high-speed video-cam and information from electro-medical apparatus.
The simple device and methodology described here can provide various basic gait parameters including step count, cadence, and step duration, in addition to the ability to distinguish between normal, disorders or disabilities gait modes.
However, this gait monitor may be augmented with additional sensors to estimate the distance of walking subjects and evaluate average walking velocity; enabling the calculation of additional gait characteristics such as average step length and average stride length. These parameters can be used to detect various gait anomalies or to develop a system to compensate some disabilities or to rehabilitate the person after a stroke or a loco-motor trauma.
These gait laboratory equipments and analysis techniques yield excellent and detailed gait characteristics and enable clinicians to prescribe an appropriate intervention or rehabilitation plan. But, first of all, it is very important to know and to understand the impact of possible pathologies in the human loco-motor system and to have such information before starting the tests and the limits of human supportability.

3. Methodology for data acquisition

Because it is very important to know and keep the environment recording conditions in the same limits and values for each investigations we're recording all parameters for the same person in the same day.
During the first step of investigation we're recording the physiological information about weight, height, blood pressure and pulse, oxygen quantity in the blood, lactic acid and quantity of glucose and temperature (fig.3.).
The persons participated to this investigation were monitoring three times daily (morning, afternoon and evening) to have all kind of information's about the variations of these parameters in the day time or about the variations of values for human body weight.

Fig.3. Example of the subjects' physiological information recordings

It was very important to know and to record the special situations for the persons who came from outside, in different moments of the day (morning, afternoon or evening) and having not any neuro-motor disabilities.

For that we're simulating in the laboratory such conditions using an ergometer bicycle and running belt to obtain the information's about the quantity of effort develop by this person and the influence of the urban environment behavior.

After these initial information's we establish the configuration of the recording setup using a structure of five markers attached on the human body in the most important joints of the loco-motor system, a black costume and also we use a high-speed video-cam type Fastec with 500 frames per seconds.

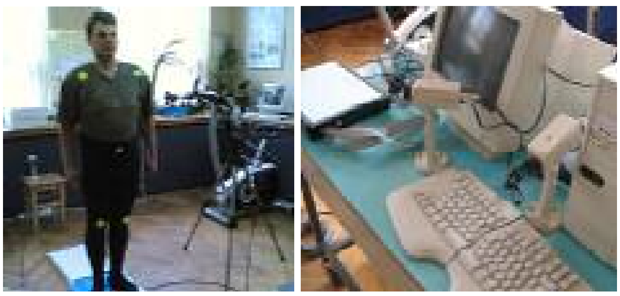

Fig.4. System with markers on human body joints

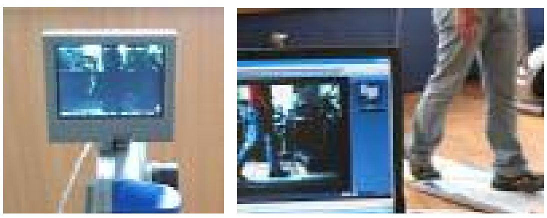

Fig.5. High-speed video-cam with recording laptop

Fig.6.The recording of the subject's positions in walking actions

4. Results and conclusions

Using this system we record the images of the walking process with high-speed video-cam and according to a methodology we extract the important sequence of frames with the human gait on the force plate it was possible to trace the knee joint marker trajectory during the movement.

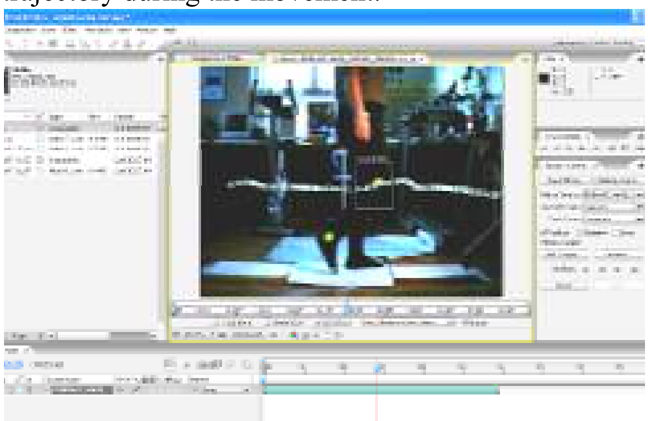

Fig.7. Marker knee joint trajectory in normal gait

This recording is analyzing at the same time with the values of the forces developed between leg and ground surface, in walking process, human subject starting with right or left foot. It can prove that this force value on the Oz axis, measured before human effort state is bigger than the same force measured when the human subject has made an effort of 30 minutes on the ergometer bicycle; the recordings before effort are presented in the fig.8-9 and the recordings after effort in fig.10-11.

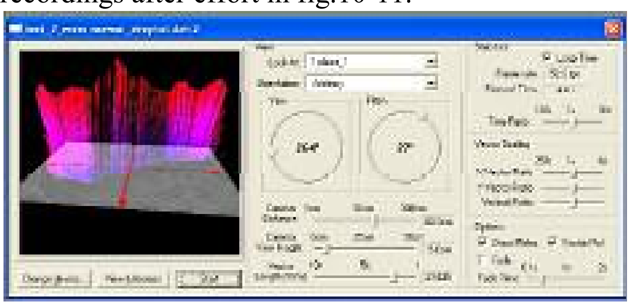

*Fig.8. The 3D shape of the trajectory **before** effort*

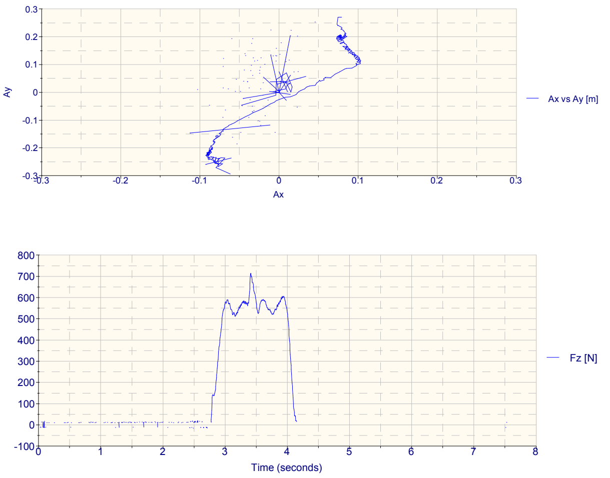

*Fig.9. 2D trajectory and force diagram on Oz axis for the right leg in normal gait **before** effort*

All forces values in first situation: before effort, starting with right leg in normal gait is presented in table no 1. and the same values for second situation: after effort, starting with same right leg are presented in table no 2.

Table no 1.

parameter	min	time	max	time
Fx [N]	-29.885939	3.952000	59.386116	3.404000
Fy [N]	-55.356422	2.948000	70.493988	4.048000
Fz [N]	-14.746978	2.488000	714.060059	3.412000

Table no 2

parameter	min	time	max	time
Fx [N]	-54.650692	3.932000	53.298477	3.356000
Fy [N]	-51.933094	2.832000	84.120758	3.976000
Fz [N]	-15.119294	9.616000	672.568665	3.380000

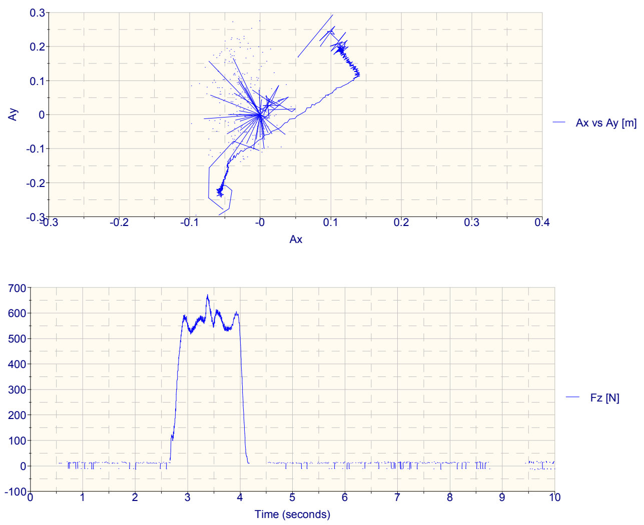

*Fig.10. 2D trajectory and force diagram on Oz axis for the right leg in normal gait **after** effort*

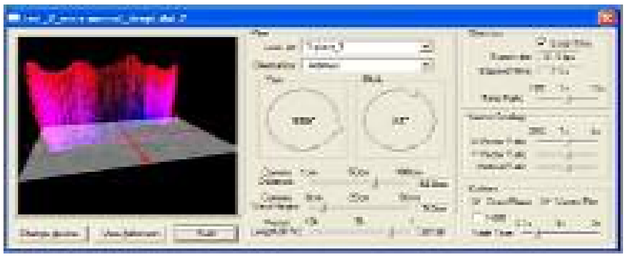

*Fig.11. The 3D shape of the trajectory **after** effort*

It is very obvious that in the situation - *before effort* - the person had a more equilibrated movement and the force on the **z** axis is bigger than the same force in the investigation-*after effort*-and the trajectory of walking on the plate had a continues shape while duration was also bigger than in the same situation. Also the values of the moments developed in the movement process on these three directions were modified from a small value before, into a big value (around 100 Nm) after the effort because it appears disequilibrium in the gait process. These situations conclude that the person having an important effort level could have a disequilibrium of the leg in gait action that allow to induce a loco-motor trauma even if he walks normally. It is most important especially for the people having prosthesis for knee or hip to be evaluated and measured by this methodology to know the limits of the gait process, the positions of the legs in stepping or walking actions or the speed and forces developed during gait process. Also these values are important to futures researches to analyze, for normal or non-normal gait, the human limits of the effort or health capacity at different ages or the influence of other physiological factors.

Acknowledgements

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