Analysis and quantification of human subject stability behaviour under visual and motor perturbations

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Abstract: - In this paper we presented some considerations concerning computerized analysis of a complex and flexible methodology used to evaluate and investigate the human performances limits in different activities situations and in bipodal posture. In the first part of the paper we reviewed some points related to the theoretical aspects of biomechanical studies for stability and equilibrium. In the second part of the paper we describe the research methodology as well as the experimental system integrated with the analysis procedures. In the final part we present the analysis results and conclusions.

Key-Words: - posture, stability, force plate.

1 Introduction

A compact and complex structure of preserving equilibrium and respectively the human body stability will always be based upon the information resulting from the sensorial-motor control system, whose "outputs" can be mostly irregular due to the random initial information.

Even when a healthy individual human body attempts to stand still, without any kind of movements, the center of gravity of this body and the center of pressure (COP) under his feet continually move in a chaotic manner. [1]

A series of external factors acting upon the human organism to a greater or smaller extent, along a variable or constant period represent the source of functional elements interacting with the human body and establish these chaotic movements.

The importance and influence of the external factors, from environment upon the human body is well-known, such as: ground resistance and elasticity, acceleration, gravitation, temperature, pressure and humidity. At the same time, the human body motion itself is the one influencing its evolution, changing even its structure, making it fit to achieve more and more complicated movements.

We can thus state that the human body structure consists of functional structures, created by dedicated function, with the purpose of creating functions [2].

"Posture is a composite of the positions of all the joints of the body at any given moment" [3].

An ideal posture is defined to be stable because the postural alignment maintains the body's mass over its base of support, also minimizes stress and strain on tissues statically all time and dynamically, during movement and minimizes energy cost. [4]

But in order to analyze, at its entire complexity, the human body balance and posture it is important to consider a series of factors like: the muscle-skeletal system, sensorial elements organization, motor coordination, environmental adjusting parameters, orientation and perception abilities and not in the last, the central controlled predictive actions set.

Also in order to analyze the way of keeping posture stability, we have in fact to analyze the alignment of the human body about the gravitational axis, called gravitation line. In the sagital plane, the gravitation line is located in front of the ankle joint's lateral axis, producing an ankle dorsal-flexion moment, requiring activity in the ankle plantar flexors. The line is also anterior to the knee joint's lateral axis, producing a knee extensor moment, requiring no muscle activity but a passive tension in posterior knee ligaments. From the point of view about the hip joint, the gravitation line is placed posterior and lateral, producing a hip extensor moment, having no muscle activity only passive tension in anterior hip ligaments (iliac-femoral ligament). Gravitational force, acting at a distance from the axis of the hip joint, produces a posterior pelvic tilt [4].

2 Analysis of the implications of sensorial stimulus on the keeping human posture and stability

Because the human body is not a homogeneous structure, in the activity of establishing the evolution of stability in different movements for stability it is very important to calculate the centroid. The centroid is the point that defines the geometric centre of a human body. If the material composing a body is homogeneous, the
weight can be neglected, i.e. centroid coincides with the center of mass point (COM) [5].

For example, normal activities process causes many changes to the neuromuscular system of a human being restricting his stability and balance capabilities.

It is very important to study the changes in the working activities of subjects especially when these activities are daily automatic movements. Because these changes sometimes result in an increased number of back pains and neuromuscular disorders or falls during daily working it is very important to analyze the influence of the automatic movements to the whole human body stability (static and dynamic).

In order to understand and to analyze the stability of the entire human body it is necessary to study and classify the equilibrium states

- **stable equilibrium** occurs when an object is placed in such a position that any disturbance effort would raise its COM and tends to fall back in its original position,

- **unstable equilibrium** occurs when an object is placed in such a position that any disturbance effort would lower its COM and tends to fall into a more stable position,

- **neutral equilibrium** occurs when an object is placed in such a position that any disturbance effort would not change the level of its COM and tends to fall into a more stable position.

The most important fact is that the location of COM remains fixed as long as the body does NOT change its shape; the generally accepted location in the human body is at ~57% of the standing height in males and ~ 55% of the standing height in females. COM varies with body build, posture, age, and gender also the weight for infant > child > adult (in % of body height from the floor).

Centre of Pressure (COP) represents the point where the resultant of all ground reaction forces acts and the COP parameters are:

- absolute position of the COP in the support directions
- movements of the COP into the support surface;
- safety margins or limits of the support surface;
- The measurement of the position of the COP is possible using the single-force-platform method and processing data system [5].

### 3 Experimental setup

Following the human subjects behavior analysis under visual stimuli, we proposed and developed a modular recording structure, in real time of the human body manifestations within in pre-established environmental conditions. The structure of the recording equipments of the subject’s biomechanical behavior consisted of: Kistler force plate, Bioware and PeopleSize software, anthropometric and subjects dimensional analysis devices and various environmental and perturbing, continuous or intermittent light sources.

The main measuring element is the Kistler force plate, which allows the values acquisition for the forces and moments developed by the human body, along the three directions (X, Y and Z), during an established period of time according to the experiment requirements.

The corresponding soft for the values acquisition is Bioware, which allows the recording of the forces and moments values, measured along the three directions by help of some piezzo-electric sensors of the force plate.
The used light sources were located in front or lateral about the subjects’ heads (fig.2.), which stood in bipedal position and worked intermittent (stroboscopic), continuous, mono-lateral or bilateral, aiming each time at the simulation of real displacement or stationing conditions.

The analysis performed upon the subjects started by establishing an investigation protocol, which aimed at a large range of measuring the bipedal stability (big support base with different polygons, small support base trapeze shaped, open or close eyes and arms along the body, in different moments of the day – morning, lunch and evening) and with different levels and sort of effort stimulated into human body by an ergometric bicycle.

The subjects were subjected to various effort level perturbations, continuous or briskly, with different intensities and along various time intervals.

4 Results and conclusions
For the results exemplification we chose one of the subjects, from experimental sample (7 human subjects having different ages, and anthropometrical conditions) having the weight 80,4kg, female, aged 52, that was recorded in the above mentioned conditions, was instructed to maintain a bipedal position with big base of support, arms along the body, open eyes, look ahead and no light stimulus, during three moments of the day, the results of the Fz force variation is presented in fig.5.

As we notice from the diagrams above, the changes in Fz variation, in determining stability are more obvious at the beginning of the recording interval when the subject during the afternoon (fig.5b) and are more powerful during the evening recording (fig.5.c.), when the subject presented a higher degree of fatigue but in a uniform variation range. The most important manifestation in recording the subject's stability is highlighted in the significant changes of the force Fz during the morning time. The stability areas determined by the oscillations' amplitudes variation of the COP projection on the support surface are confirming the subject's instability during the morning towards the recording end. (fig.6.a)
After the human subject's behavior recording stage without inducing a controlled fatigue state we performed an analysis of the same parameters in case the subject was subjected to a controlled effort (use of ergonomic bicycle). The results in the same category as above are presented in fig.7a-d.

The subject is a male, aged 21, no previous health problems and the recording took place in the same environmental conditions during a maximum activity period (stability area in fig.7.a. before effort, with open eyes, stability area in fig.7.b. after effort with open eyes, force Fz variation in fig.7.c. before effort, open eyes and force Fz variation in fig.7.d. after effort, open eyes). The force plate and the data acquisition system were calibrated for each measurement as the subjects have different weights and the filtering basis will change.

From these recordings and according to the initial conditions and the demands of the researches we can conclude: that the most important force values are the components on the direction Oz because they can establish the amplitude of the balance (moments) in other two directions Ox and Oy. Also the changes in foot position have been found to affect measurements of standing balance, force and stability surface and in normal conditions the size of the support is a primary determiner of stability. Other influences were the light stimulus on the visual system because they are the most important stimulus inducing the instability that will be bigger in the open and fixed oriented eyes position than free gaze even if the optical stimulus was the same. This situation is due of the unknown visual external stimulus reactions and concentration on the automatic activities.

ACKNOWLEDGMENT
These researches are part of the Grant PNII-IDEI 722 and IDEI 744 with CNCSIS Romania and we’ve developed the investigations in Department Advanced Mechatronic Researches from University Transylvania Brasov.

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