Measuring of human body stability – part of bio – behavioral studies

MIHAELA BARITZ¹, LUCIANA CRISTEA¹, DIANA COTOROS²
¹Fine Mechanics and Mechatronics Department
²Mechanics Department
University TRANSILVANIA of Brasov
Address: 29 Eroilor St., Brasov 50036
ROMANIA
mbaritz@unitbv.ro , http://www.unitbv.ro

Abstract: - This paper presents some considerations concerning measurements of the human body stability as a main part of the bio-behavioral analyses in order to optimize occupational comfort or detecting some mobility deficiencies or even attention failures. The methodology and the investigations procedures are presented in the second part of the paper and in the final part the results and the conclusions of this work are presented.

Key-Words: - Stability behavior, movement, human body, force plate.

1 Introduction

The most important stance of the human body is represented by the bipedal, vertical, upright and supported on a normal base (closed insteps – small base) posture, as being an initial, intermediate or even final state for the locomotor function and also for the rest of the movement actions on any direction (jumps, bends, torsions).

The stability stance as well as the integral balance around the equilibrium position are determined by the health level of the entire human body and may constitute clear informational sources for the human behavior evaluation in any situation. The small deviations of the human body posture around the vertical direction determine the occurrence of a torsion moment, which acts upon the entire structure and may unbalance the human body or may create a vibration state. However, this process of corrective torque generation is not fully understood and controversy remains regarding the organization of sensory and motor systems contributing to the postural stability of the entire human body.

Balanced state of postural sway is controlled by central nervous system, and the upright stance cannot be sustained without this control. It is widely accepted that the corrective torque is generated through the action of feedback control system; the input sources include visual, proprioceptive and vestibular system [2].

Figure 1 shows the block diagram of the postural sway feedback control and also a simplified pelvic structural model during static upright stance. A, B are the masses of legs, C is the mass of pelvis and D is the mass of upper trunk. Because the lumbar-sacral always sways in inverse direction of the ankle joint with the same value of θ, the upper trunk is kept perpendicular to the horizontal.

In order to locate the center of mass it is necessary to establish some main principles:
- its precise location depending on individual's anatomical structure;
- habitual standing posture;
- current position;
- external support;
- location in human body;
- variations with body build, posture, age, and gender
  - infant > child > adult (in % of body height from the floor);
  - generally accepted that it is located at ~57% of standing height in males, and ~ 55% of standing height in females;
- Location of COM remains fixed as long as the body does NOT change shape.

The maintenance of equilibrium in standing position is one of the most important activities for two main
reasons: firstly, the center of mass must be located in the support area; secondly, for a major period of the standing action, the body is supported first by two legs and after a short time by a single limb with the center of mass inside the base of support but with the tendency of going outside it.
In elder people especially, up to 70% falls occur during standing and of course, locomotion action. [3]

By the static stability margin is meant a distance of the GCOM from the edge of the support polygon, measured along a current vector of motion of the gravity center, where:

\[
\begin{align*}
x_{GCOM} &= \frac{\sum_{i=1}^{n} M_{xi}}{\sum_{i=1}^{n} F_{xi}} = \frac{\sum_{i=1}^{n} m_i x_{ci}}{\sum_{i=1}^{n} m_i} \\
y_{GCOM} &= \frac{\sum_{i=1}^{n} M_{yi}}{\sum_{i=1}^{n} F_{yi}} = \frac{\sum_{i=1}^{n} m_i y_{ci}}{\sum_{i=1}^{n} m_i}
\end{align*}
\]

and \(m_i\) is mass of the \(i\)-th body, whereas \(x_{ci}, y_{ci}\) denotes location of the center of mass of the \(i\)-th body.

2. Experimental setup for investigation

In order to start the investigation we analyzed and realized a data acquisition structure based on an assembly of measuring human physiological parameters controlled by a computer unit.

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 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 eyes and arms along the body, in three moments of the day – morning, afternoon and evening).

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.

We also aimed at the fact that the bipedal position of each subject is centered on the plate, with no high heels shoes, arms relaxed along the body, open eyes and the eyes oriented straight ahead.

In first stage of the experiments we established and kept the parameters of the laboratory environment. Temperature into laboratory was 25\(^\circ\)C, air humidity 80% and atmospheric pressure 755 mmHg.[4]

In the second stage we measured the physiological parameters of the human subjects (weight, height, age, pulse, blood pressure) in relaxed stance, without any health problems and with a good metabolism (example: blood pressure 155/82 mmHg, pulse 91, face temperature 36,7\(^\circ\)C, height 175 cm, weight from 50-125 kg).

All these parameters are necessary to establish a common modeling base to measure and to evaluate the human body stability behavior.

![Fig.2.](https://via.placeholder.com/150)

By this proposed investigation structure we establish that the human subjects are analyzed and compared to the corresponding virtual models of the stability measurements simulations in order to correlate all the influence factors. [4]

Thus, in fig.3 we present the data acquisition concerning the stability of a human subject, female, height 1,7m, age 53, no health problems, wearing far sighted glasses, weight 80kg, for which we analyzed the stability area and the force evolution along Oz in three moments of the day (morning, afternoon and evening) without any source of additional effort induced to the organism.

As we can notice from the diagrams analysis in fig.3, the evolution of the stability area in this case presents a compact and symmetrical surface for the first time in the morning, a smaller and more concentrated area for the afternoon and a substantial change of balance – slightly shifted along Ox for the evening recording.
This manifestation can be found in all the analyses performed on the selected subjects allowing a unitary evaluation of the stability area.

As far as the recorded force on Oz is concerned, these results are presented in fig. 4 (up – morning, middle – afternoon, down – evening).

The recording time was each time the same – 16 sec and the data set was stored in the measurements database used for evaluation.

In the case of force evolution analysis we observe the same type of manifestation for the recording performed in the evening, emphasized by an increase of the variation limits of the force along Oz, but also by a higher frequency of their occurrence, values that indicate an increased instability of the human body and a fatigue state at the inferior limbs level.

In this situation and correlating with the age and the influence of the poor sensorial system we may confirm that the installation of the fatigue state as a follow of a normal daily activity takes place in the second part of the day determining a motor activity deficit and the diminishing of the orientation perception.

In the case of a male subject age 34, no health problems, not wearing glasses, weight 97kg and height 1,7m, the evolution of stability area in the three moments indicates a more compact and symmetrical shape around the theoretical equilibrium position as we can observe in fig. 5, and the forces variation diagram is changing towards the diminishing of the oscillations number for the recordings situation related to those in the morning, fig. 6.

This fact establishes a more equilibrated behavior for which the fatigue due to daily activity does not influence the motor capacity and also does not reduce the resistance to effort.
3 Conclusion

In the diagrams shown in the figures we presented the analysis of the evolution of parameters during these investigations, made by statistical methods. 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.

By the future researches we are going to analyze the influences of the visual and audio stimuli upon the human body equilibrium in order to obtain a correlated evaluation of the human subjects stability, subjects involved in technological activities.

4 Acknowledgment

These researches are part of the Grant nr. A1088, A1058 and PNII-IDEI 722 and 744 with CNCSIS Romania and we’ve developed the investigations with apparatus from Research Platform “SAVAT”, Division “CATEPAC” from University Transilvania of Brasov

References:
[3] J. Mrozowski and J. Awrejcewicz, ZMP and GCOM criteria as a base of assessment of the human gait stability, Department of Automatics and Biomechanics, Technical University of Łódź,