CORRELATIVE ANALYSIS OF THE INFLUENCE ON HUMAN BEHAVIOR AND WORKING COMFORT DUE TO REPETITIVE TECHNOLOGICAL PROCESSES

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Abstract: In this paper we presented some theoretical and practical studies related to the analyses of human behavior in repetitive actions during technological processes. In the first part of the paper we presented the theoretical aspects of correlative analyze using *Pearson product-moment correlation coefficient* and analyze of variance (ANOVA) method. In the second part of the paper, the investigation methodology of the human behavior in repetitive activities were presented and analyzed. In the third part of paper we present measurements data and the procedure for performing measurements upon the human sample and also the possibilities to develop an objective method based on correlation technique. The results and data processing examples are presented at the paper final part.
Key words: correlation, tehnological process, human behavior.

1. INTRODUCTION

The analysis of the human behavior during performing working activities represents at this moment a huge importance domain in obtaining performances and assuring occupational comfort. (Baritz M. & al. 2010)
The correlation theory was used to develop a complex analyze and to investigate the influence of bipodal positions of human subjects on the stability state when they raise the same weight and make repetitive movements during technological activities.
A high range of models were developed, their main feature being that the human subjects involved in working activities will be able to choose the postures allowing the human body joints to develop the highest moments and forces, in an optimal self-adjusting manner of the motion and stability mechanisms. (Tozeren A., 2000)
Some researchers like Seitz and Rothaug were developed a model based on the optimization of the predictive posture, which in its turn is based on the human posture and the information related to the strains and forces developed in the human body's segments. The strains were used in these models as constraints that come closer to the "more natural" aspects of the human biomechanics to improve the visual realism of the posture prediction. But the aspects of "more natural" regarded as subjective criteria are necessary but not enough for the validation of ergonomic analyses and for solving optimization and efficiency of biomechanical analyses. (Borg F., 2005)
Many researches suggested that the working postures should be predictive by optimization of some factors such as potential energy, deviation towards the neutral location of the joint involved by the motion, dis-comfort and tension.
The general approach is to select form a multitude of postures, that are cinematically connected to the constraints, the one that minimizes (or maximizes) an objective function. (Kutz M., 2009)
For example, some reserches suggest three solutions "keys" (the tendency of moving in sequences different body segments, preferably forward with respect to the neutral comfort position, the discomfort of motion near the limits of the joint motion range) that hypothetically are related to the human behavior in the chosen posture.
But there are many values of data in recordings on the human behavior investigations for different purposes. For that is indicated to use correlation theory and also, to establish a set of data, minimum necessary need to find the influences of different sources of discomfort or instability or energy consumption on capabilities of workers. (Baritz M., et al., 2010)
Some times, in many experimental researches are used the *multivariate analyses* and as the name indicates, multivariate analysis comprises a set of techniques dedicated to the analysis of data sets with more than one variable.
Several of these techniques were developed recently in part because they require the computational capabilities of modern computers.
Also, because most of them are recent, these techniques are not always united in their presentation,

and the choice of the proper technique for a given problem is often difficult. (Herve A., 2003)
In statistics analyze of biomechanical or ergonomic data, the **Pearson product-moment correlation coefficient** (**PPMCC** or **PCC**) is a measure of the correlation (linear dependence) between two variables, *X* and *Y*, giving a value between (+1) and (−1) inclusive. It is widely used in the sciences as a measure of the strength of linear dependence between two variables. The correlation coefficient is sometimes called "Pearson's *r*."
Pearson's correlation coefficient between two variables is defined as the *covariance* of the two variables divided by the product of their standard deviations:

$$\rho_{X,Y} = \frac{\mathrm{cov}(X,Y)}{\sigma_X \sigma_Y} = \frac{E[(X-\mu_X)(Y-\mu_Y)]}{\sigma_X \sigma_Y} \qquad (1)$$

The above relation defines the correlation coefficient and substituting estimates of the covariances and variances it obtain the sample correlation coefficient Pearson's *r*.

$$r = \frac{\sum_{i=1}^{n}(X_i - \overline{X})(Y_i - \overline{Y})}{\sqrt{\sum_{i=1}^{n}(X_i - \overline{X})^2}\sqrt{\sum_{i=1}^{n}(Y_i - \overline{Y})^2}} \qquad (2)$$

Another fundamental issue related to the correlative techniques is represented by the causality of some events that are analyzed with respect to the correlation procedures.
We found that the correlative technique does not involve causality in the way that this procedure cannot be used to intervene in the causal relations between the variables.
This is why this aspect should not signify the fact that correlations cannot point out the existence of possible causal relations.
For example in the biomechanics analyzes there is an obvious correlative relation between age and height (ideal) but less obvious and analyzed is the correlation between the psychical state and health because we cannot clearly establish which one of them is the determinant factor, the causal one and the affected one.
An important aspect is, also, represented by the linearity characteristic of the correlation. The Pearson correlation coefficient indicates the strength of a linear relationship between two variables, but its value generally does not completely characterize their relationship.
In particular, if the conditional expectation of *Y* given *X*, denoted *E(Y*|*X),* is not linear in *X*, the correlation coefficient will not fully determine the form of *E(Y*|*X).* [http://en.wikipedia.org/]
From different examples of the literature we may remark that the correlation coefficient as a statistic function cannot replace the data individual examination and their interpretation, taking into account the dependency factors.
Thus, it is enough that one value of the individual examination string is outside the other data distribution in order to produce a strong correlation process, even if the relations between the variables are not linear. Because the examinations category in case of the experiments regarding postural malfunctions analysis are strongly influenced by different environmental conditions, by different categories of subjects or by other imposed or known factors it is many times more practical to use the property of *correlation coefficient concordance* (CCC) defined as the agreement between two variables, e.g., to evaluate reproducibility or for inter-rater reliability. Reproducibility of some experiments especially in the biomechanical analysis that work with subjects' samples having different characteristics, represents one of the basic scientific methods and refers to the ability of an experiment to be accurately reproduced in another location or using different similar equipments allowing similar results. Thus, the reliability of a statistical data processing system concerning the subjects' evaluation may determine an intra-class correlation that is used in its turn as a statistic descriptor for the quantity measurements of the variables (results of determinations upon subjects), organized in groups.

2. EXPERIMENTAL SETUP

In experimental analysis performed for developing integrated correlative techniques used for the study of human factor behavior, we considered a recording system of the forces developed on the ground during repetitive technological activities, like rising and carrying the weight, or system to record the rally with hands of a dynamometer device, simulated some non-repetitive technological activities. (Mrozowski J., et al., 2007).
This equipment allows the recording of forces and moments on three directions (Ox, Oy, Oz) at the foot-ground contact, in base of support (BS), both in the static stability determination process and in the dynamic stability (fig.1.)
The used method was based upon the ANOVA model for the determined sample of 21 subjects (12 women and 9 men).
Data acquisitions were accomplished in the same environmental conditions and following the same trail of the recording procedures. (Katiyar R., 2010).

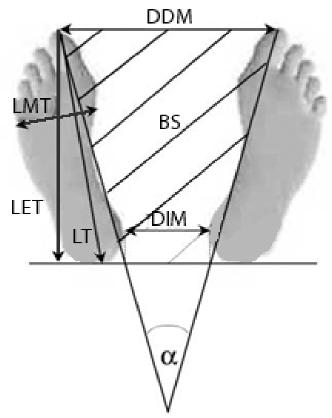

Fig.1.Anthropometrical data for base of support (BS)

For a better analysis of the correlative analysis methods we selected three recording variants having as a variable parameter the displacement direction of the tips with respect to the displacement axis.

In this respect we established three situations: *stability* without any movements having open eyes and hands near body; *movement to raise* a weight of 2 kilos in *bent motion* of the body and the *movement to raise* an object with the same weight but using *flexion of the knees* (fig. 2.)

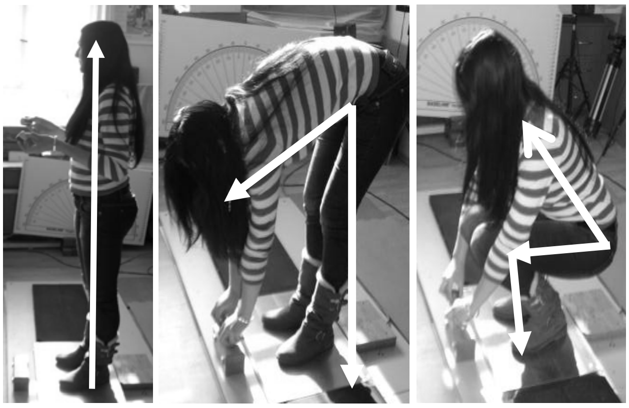

Fig.2. Recording situations to analyze the stability in working activities

The initial recordings started with analyze the environmental conditions and the job descriptions to establish the constraints and the capabilities of this

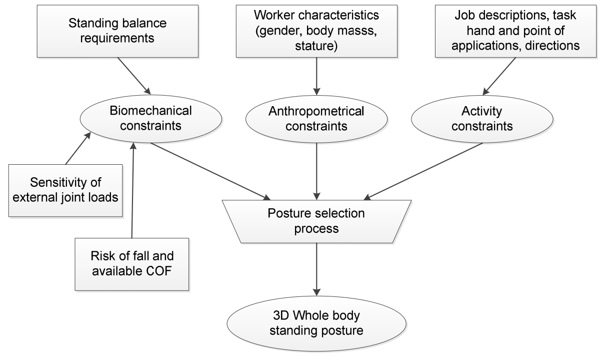

Fig.3. Block diagrame to record the data of stability and movements for raising weights

subject sample. Also was necessary to have, like initial parameters, the anthropometrical data and biomechanical constraints for each subject (fig. 3.) (Pheasant S., et al., 2006)

The variation between age and weight of the sample of subjects is presented in fig. 4 and is very important to correlate these data with the calibration of force plate type Kistler used to record the stability areas.

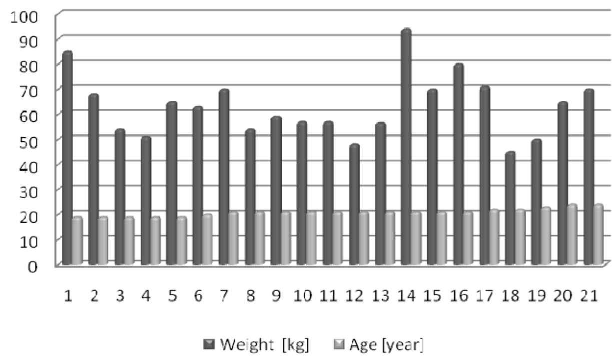

Fig.4. Variation between age and weight for the subject sample

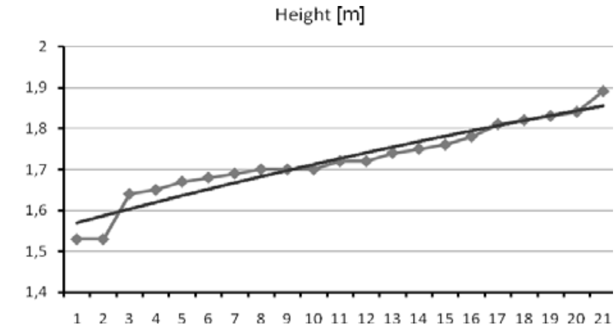

Fig.5. Variation of height for subject sample

During the recording steps each subject was training to make the same movements with the weight in hands and to do not stop before the time of recording finish. It was choosing different category of subject heights to take in acount the influence of this parameter (fig.5.), (Baritz M., et al., 2008).

The recordings are made in two sort of moving speed, slowly and fast for both type of bent. They start to raise the weight from bottom until straight position and after that put on the same place the load but using different way to recline (bent the body from hip or flexion the knees – fig.2), (Radu C., 2007).

The force plate records the evolutions of forces on three directions during each recording but also the stability area and the force moments.

Very important for correlation process, was to analyze the movement total acceleration of center of mass (COM) and to compare it with the evolution of this point, during stability recordings (fig.7., fig.10) and with the variations of force on Oz direction (fig.6., fig.9). (Blaszczyk J., et al., 2001)

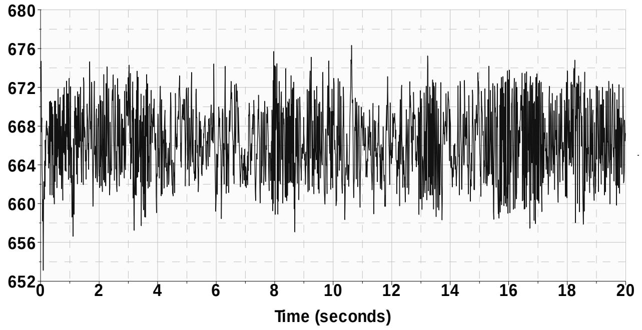

Fig.6. Force variation on Oz axis for stability (subject from fig.2.)

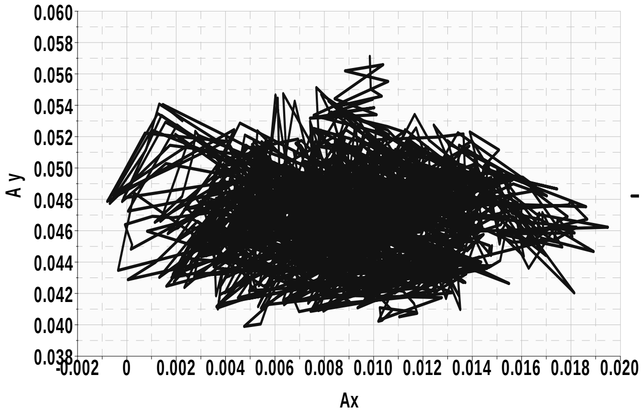

Fig.7. COM stability area variation in quiet stance (subject from fig.2.)

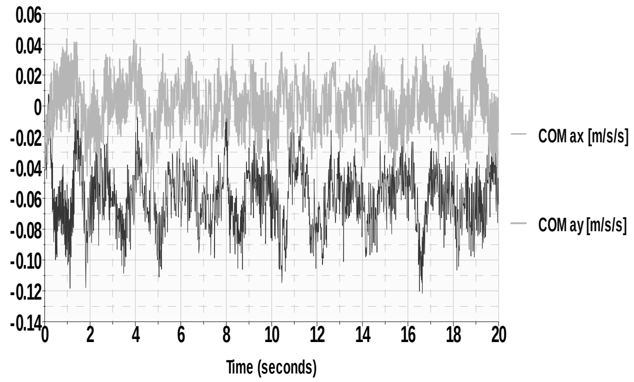

Fig.8. COM acceleration variation on Ox and Oy axis in stability recordings (subject from fig.2)

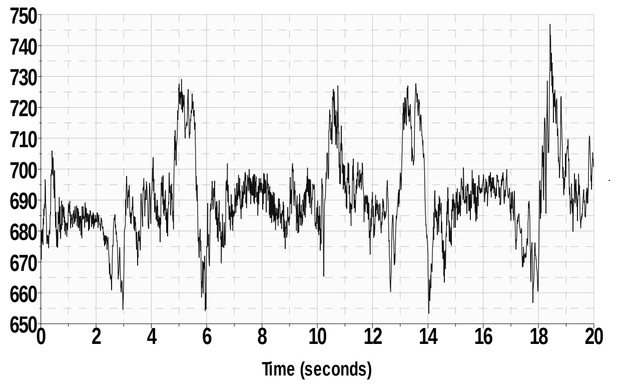

Fig.9. Force variation on Oz axis with slow bent movement and weight of 2 kilos (subject from fig.2)

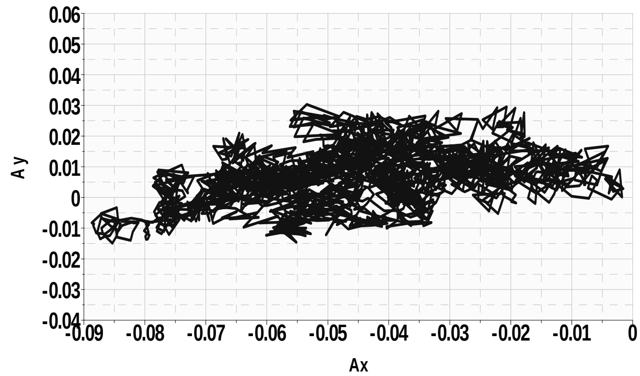

Fig.10. COM stability area variation in slow bent movement and weight of 2 kilos (subject from fig. 2.)

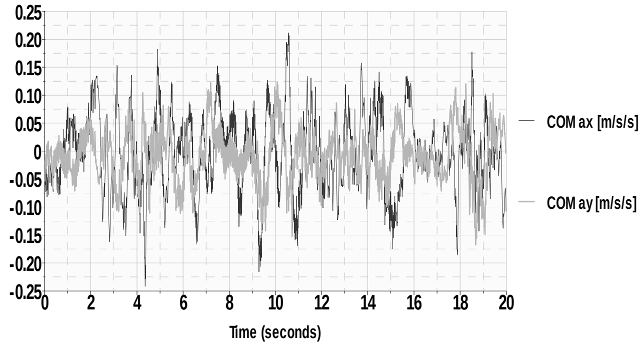

Fig.11. COM acceleration variation on Ox and Oy axis in bent slowly movement and weight of 2 kilos (subject from fig. 2)

If it is comparing the parameters (accelerations of COM in two directions) from fig.8 with the same parameter presented in fig.11 is obvious that the ”human body” makes ”effort” to establish a good biped position (in second situation when subject moves by bent the body forward), without any disturbances or defiance from central and stable position. The amplitude of moving is bigger than first situation but it had the same values on Ox and Oy directions even the movements were made only in Ox direction. When the same subject starts the second sort of recordings (fast bent) the values of forces on Oz direction are calculated and presented in fig.12, fig.13 and fig.14. The correlation ratio is in this case **+0,4539**; this value means that the behavior of human body, in the same category of movement, is not similary and the maximum vs. minimum limits of forces are very different. (Baritz M., et al., 2008)

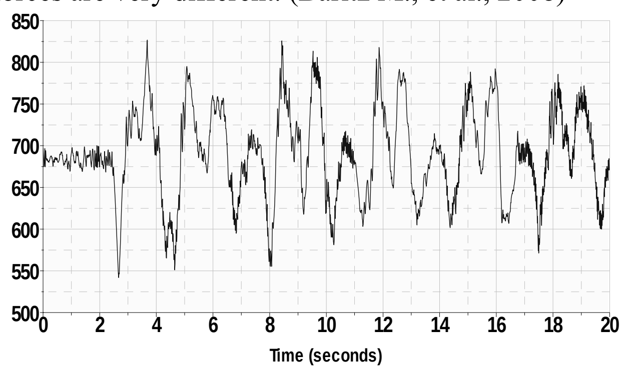

Fig.12.Force variation on Oz axis for fast bent movement (subject from fig.2.)

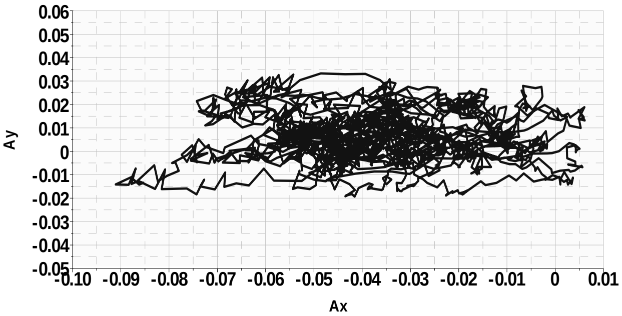

Fig.13. COM stability area variation in fast bent movement (subject from fig. 2.)

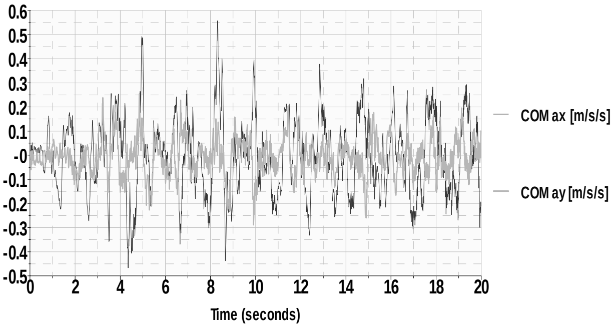

Fig.14.COM acceleration variation on Ox and Oy axis in bent fast movement with weight of 2 kilos in hands (subject from fig. 2)

From these recordings is abvious that the effort maded by ”body”, through central nervous system (CNS) to keep the direction and frequency of movements and also to keep the stability of entire human body is doing with a supplementary energy comsuption. In these cases the efforts develop a tiredness state in hands and legs muscles and if, the activities are for long durations, this tiredness affects also the attention and concentration in working activities.

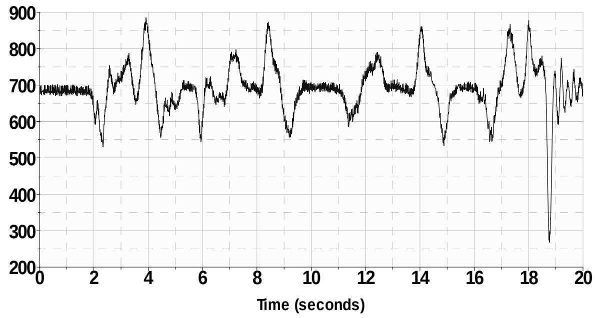

Fig.15. Force variation on Oz axis for **slow knee flexion** movement (subject from fig.2.)

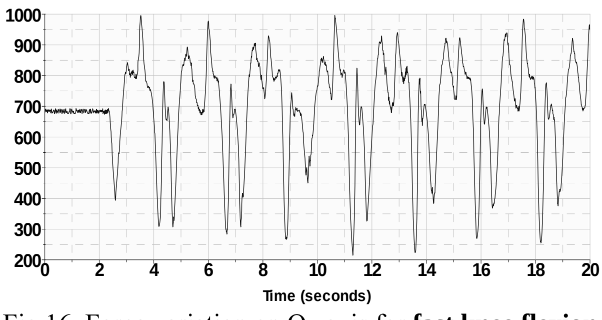

Fig.16. Force variation on Oz axis for **fast knee flexion** movement (subject from fig. 2)

The correlation coefficient is calculated from these two recordings, *slow and fast knee flexion movements* and the value is **+0,7845** which is meaning that the movements have the same trendline and the correlation is stronger than bent movement with straight legs (first case).
The same situation is showing when we analyze the stability area.

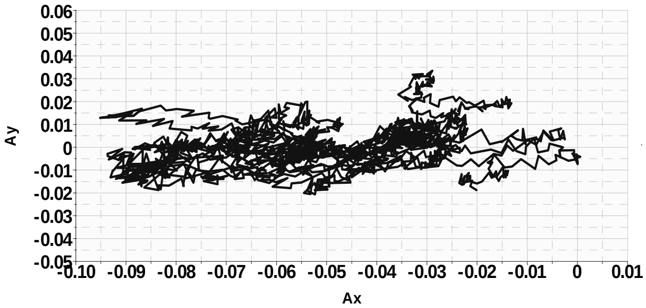

Fig.17. COM stability area variation in **slow knee flexion** movement (subject from fig. 2)

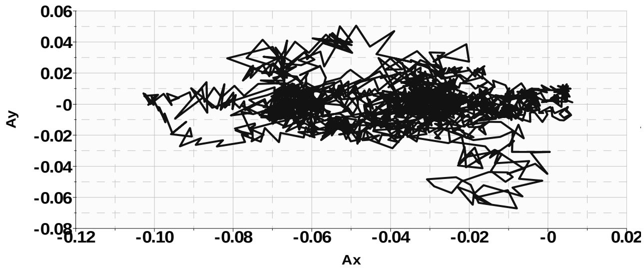

Fig.18. COM stability area variation in **fast knee flexion** movement (subject from fig. 2)

When the movement is made with knee flexion, slow and fast, the variation of force on Oz axis (fig.15, fig.16), the stability area (fig.17, fig.18) and variation of COM acceleration on Ox and Oy axis, all of them present different variations and limits of values.
When the subject was doing these two variant of knee flexion movements (slow and fast) also the stability areas are very different and denote a bigger instability on Oy direction. This instability appears because the human body trys to equilibrate the forward body movements when the subject picks up the load. This amplitude of instability creates sometimes a supplementary tension in muscles of legs because the body needs to keep a simetrically position and the same direction of movement.

3. RESULTS AND CONCLUSIONS

Following these multiple analyses, an evaluation structure was created, based on advanced techniques and focused on the study and characterization of the bio-behavioral performances.
In the same way, it was taken in account, for the locomotion system (by configuring the system in relation to the visual, acoustic and thermal stimuli), a future development towards and complementary analysis of the upper part of the human body.

This system is completed by an investigation technique with computerized correlated systems for obtaining results in real time and setting proper sequences for each subjects sample selected for different assessment procedures.
In the same context and by this proposed investigation structure we establish also that the human subjects are analyzed and compared to the corresponding virtual models of the stability or walking measurements simulations in order to correlate all the influence factors from environmental space. (Cotoros D. & al., 2009)
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 the 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. In normal conditions the size of the support is a primary determiner of stability.
The light stimuli on the visual system were other kind of influences, because they are the most important stimuli inducing the postural instability. It is obvious that the postural instability was bigger in the open and fixed oriented eyes positions than free gaze even the optical stimulus was the same.
This situation is due to the unknown visual external stimuli reactions and concentration on the automatic activities of the human subjects.
Other applications of these flexible methodologies and recording structures represent the object of more extended researches, which allows developing of an investigation-assessment-rehabilitation protocol for the hip implant patients, for the patients with different walking impairments, for disabilities developed into working activities or for analyzing the ergonomy of a working place. (Jiang Y. & al., 2006),
Thus, to obtain a quick response in the analysis of comfort type and forces developed in the subject postural stability, this methodology can estimate and correlate data for different recording moments with environment parameter and other conditions.
Respectively, it was using this correlative analysis for different anthropometrical dimensions or mobility restrictions to improve the ergonomy and environmental futures of working places.

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