TRAMA TRAining in Motion Analysis

Falling Risk in elderly

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Falls represent one of the most serious problems associated with adulthood [3]. They can mark, not only the beginning of a decline in function and independence, but also, they are the leading cause of injury-related hospitalization. More than one third of adults, 65 years and older, falls each year. Moreover, this rate increases to 40% among those over the age of 80 years. Falls are a serious cause of injury deaths [1].

Some degree of imbalance is present in all individuals older than 60 years. This is the result of a generalized functional degradation. Initially, the imbalance is situational, that is to say, it manifests when the righting reflexes cannot meet the demands of a challenging environment, such as a slippery surface [2]. As the functional degradation increases, the imbalance occurs during everyday activities. Independent ambulation becomes difficult.

Tests of postural stability can identify, independently of age, individuals who are at risk of falls and fall-related fractures

In this work, a technique based on control theory to observe stability was applied to real responses of the movements of human heads.

A stimulus-response technique was employed to evaluate some factors that determine the causes of falls in elderly.

Head was chosen for the study because measurements of movements of head, ankle, knee and hip joints, performed to the erected human body, confirmed that this structure can be considered as an inverted pendulum above the ankles.

In this sense, control theory criteria were used for analyzing the movement responses of the human head. As a complementary contribution to this proposal, external stimuli were applied to the subjects in the form of infrasound waves to evaluate how the pressure generated by these mechanical artifacts found in the environment interact with the muscle structure and the vestibular system of people, that is to say, with muscles, joints and head movements in order to correlate the risk of falling with some mechanical artifacts that we cannot hear but are present around us. A baropodometric platform was used to evaluate the changes in the amplitude of the sway by means of the Romberg index when the subjects were submitted to visual and infrasound stimuli.

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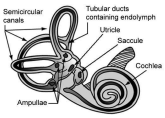

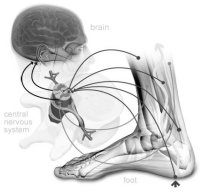

Balance and equilibrium in humans require the contributions from vision, vestibular system, proprioception, muscle strength and reaction time. With increased age, there is a progressive loss of functioning of these systems, which leds to balance deficits.

Common procedures for risk of falling evaluation

The most important companies in the world BTS (Italy), Vicon Motion Systems (UK), MEDICAL MOTION (USA), APAS ARIEL (USA), offer equipment and systems for movement analysis. Some Researchers try to study the risk of falling, by observing and analyzing the capacities of a subject to develop some actions, common spatial and temporal parameters are used. An important limitation while working with elderly is the rejection of subjects to be submitted to movement analyses, mainly if some actions are asked to be performed.

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So

This thesis is focused to contribute with the following actions:

1) To determine some simple, secure, and reliable tests to identify those persons who may be under risk of fall.

2) To determine an objective indicator of falling risk pursuing falls prevention, through the information obtained from the motion analysis of the head, when a person is submitted to visual and mechanical stimuli.

Subjects

A total of twenty eight elderly subjects, 65 -83 years old and eight people, 30 – 40 years for control were recruited from a group of volunteers who attended the invitation for research purposes. Three trials per subject were performed

Fifteen subjects were submitted to a visual stimuli, five subjects to an infrasound (mechanical) stimuli and finally eight subjects were evaluated by means of the Romberg test .

The tenets of the Declaration of Helsinki were observed, and the study was performed with the approval from the institutional ethics committee. Informed consent was obtained after the nature of the study had been fully explained.

Cognitive constraints in elderly people represent serious disadvantages to follow instructions. In this sense, one person did not participate in the study.

Exclusion criteria, non apparent vestibular disorders, non visual disorders and non ankle injuries.

Instrumentation and Laboratory Dimensions
A digital optical system (Ariel Performance Analysis System, USA) was used for 3D measurements of head displacements. Sphere-shaped infrared reflexive markers (BTS Bioengineering, Italy), 15 mm diameter with a plastic extension were used. The system included four infrared cameras (Bristall, Mod. CAM817M, NTSC system, China), and 3.6mm fixed focal length and IR radiation equipped. Volume for measurements was 2.7 m3 dimensioned as 1.8 m high, 0.82 m wide and 1.9 m long, all of this into our lab. with 3.46m height, 7.2m length and 5.5m wide, Image capture and processing was performed by using the 4-channel 133 MHz Picolo Tetra card (Euresys Company, USA) and a generic PC implemented with a hard disk Sata type 160GB and 2GB in RAM, respectively. Configuration of the optical system included: 30 f/s frame ratio and five-order polynomial filtering at 0.4Hz 3dB cutoff frequency. Frame 44synchronization was done by the use of a lamp whose light temporally labeled the frames from all the cameras as a reference. Further processing was performed by the use of the optical system software to obtain the angular displacement, speed, acceleration signals, and image sequences versus time.

Markers location on a 77 years old man

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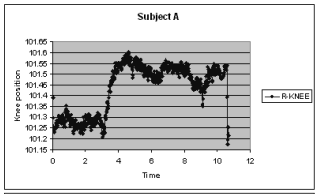
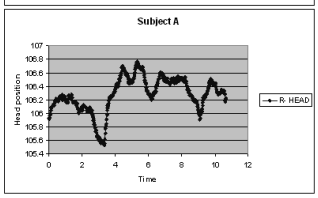
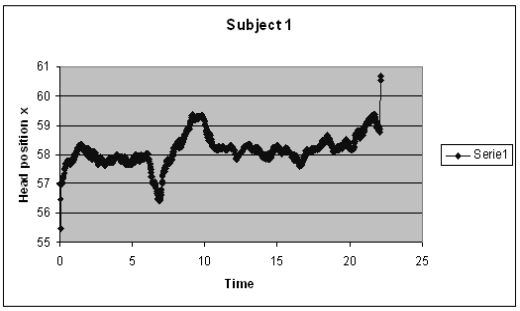
In order to discard some strategies of ankle, knee or hip, we acquired the information from ankle, knee, hip, shoulder and head marker signals and we observed the following: Ankle movements, these are negligible, knee signal recording is very similar to that recording from the head but the magnitude is almost negligible







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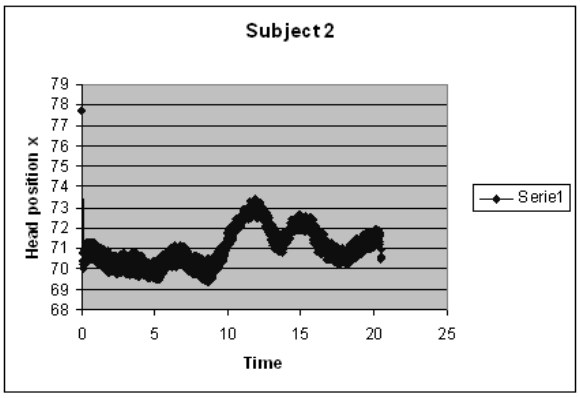

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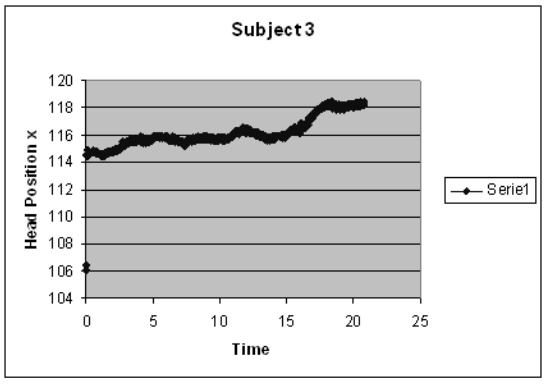

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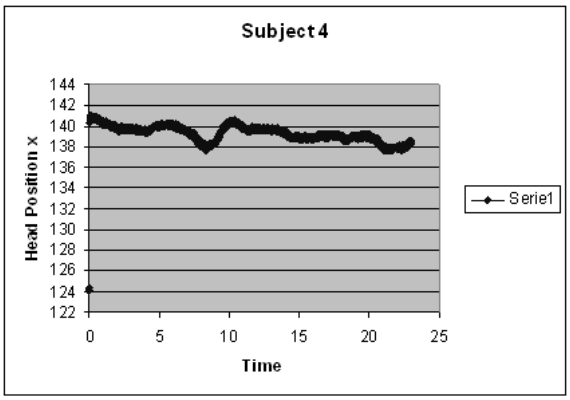
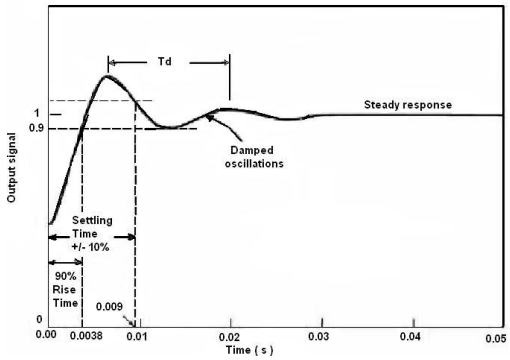


The typical behavior of a second order function in control systems is shown in figures 13A and 13B, including damping factor, nature frequency and times involved in the model.



A customized algorithm for the regression was developed. It is based on the mathematical model, represented by the second-order differential equation

$$\frac{d^2y(t)}{dt^2} + 2\zeta\omega_n \frac{dy(t)}{dt} + \omega^2_n y(t) = \omega_n^2 U(t) \qquad (1)$$

The solution of Eq. (1), expressed in Laplace transform is:

$$\frac{Y(s)}{U(s)} = \frac{K\omega_n^2}{s^2 + 2\zeta\omega_n^2 s + \omega_n^2} \qquad (2)$$

In control theory, the complex plane is known as the s plane. It is used to visualize graphically the roots of the equation $s^2 + 2\zeta\omega_n^2 s + \omega_n^2$ describing the system behavior (the characteristic equation).

3D Motion of head, while stimulus is being applied, can be represented by a second-order mathematical model [8], which was determined by using a multiple regression technique, under the MatLab platform. These responses were analyzed considering damping factor and nature frequency of the model to solve the representative equation determining the corresponding roots called the poles.

Multiple correlation was done designing an adjusting algorithm, the error value is the difference between the real signal and that produced by the mathematical model with ζ and given values. The algorithm is iterative, one parameter of the equation is fixed and the other is modified until the error measure has reached a minimum. This iterative process is repeated for other fixed values. When the range of values to be analyzed is finished, a minimum error is obtained and the values for the best fitting, for ζ and were determined.

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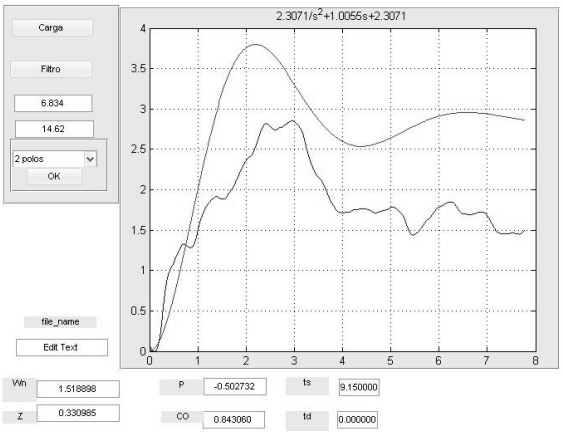

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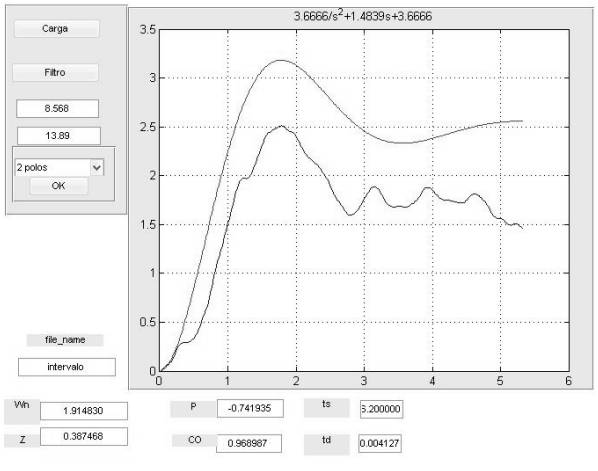

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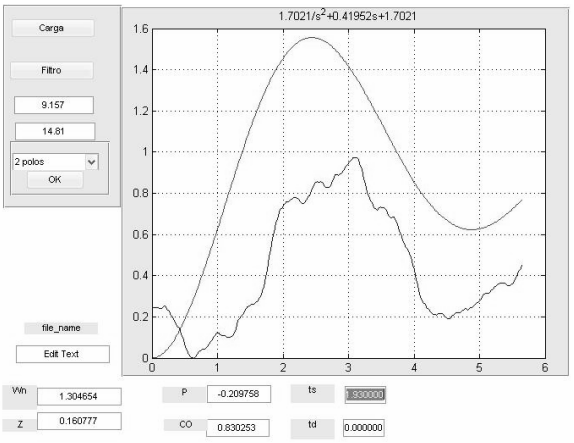

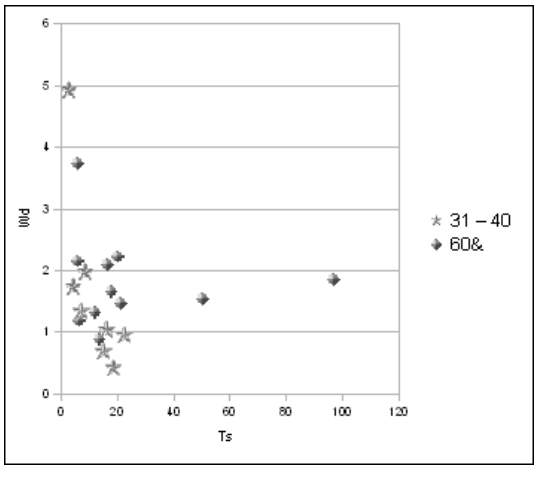

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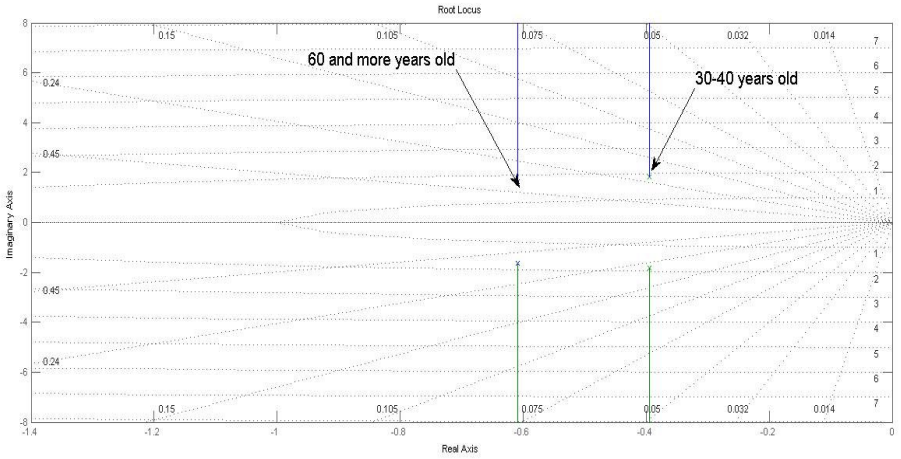

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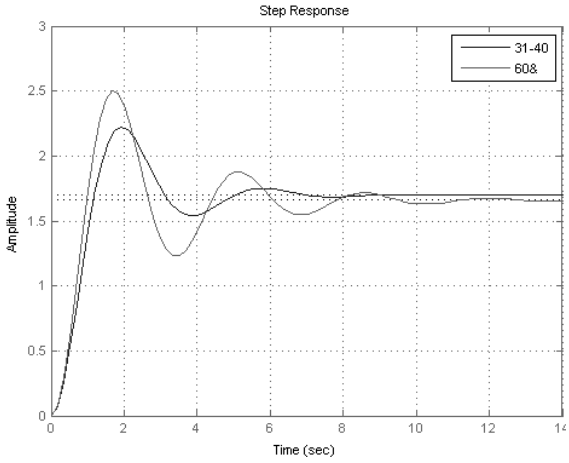

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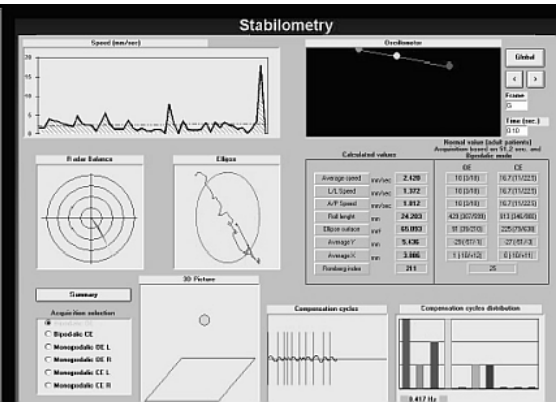
Sway Graphs

Each investigation provides values for:

- Sway surface
- Length of trajectories
- Stabilograms
- Radar balance
- Romberg Index
- Postural rectangle
- Sway velocity



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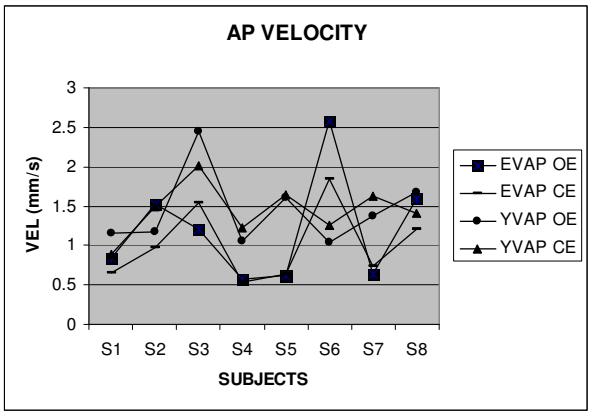

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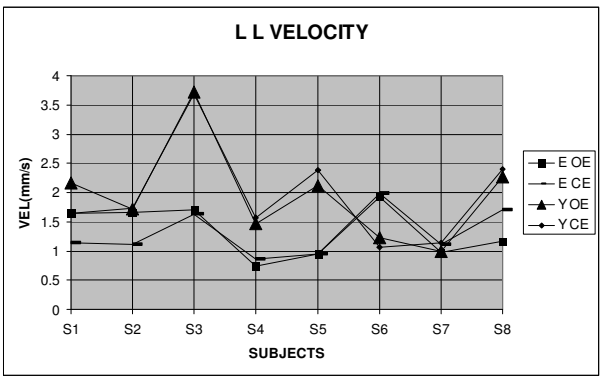

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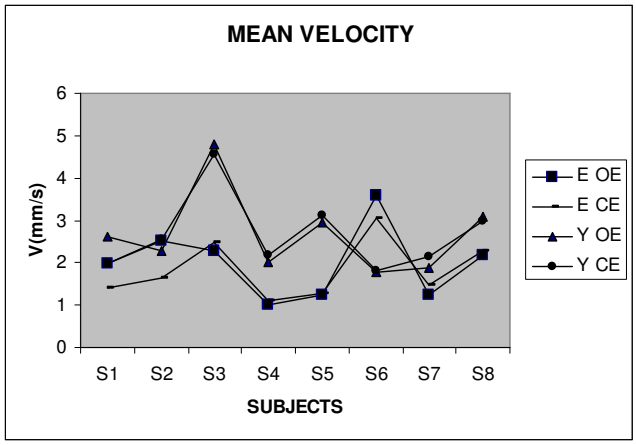
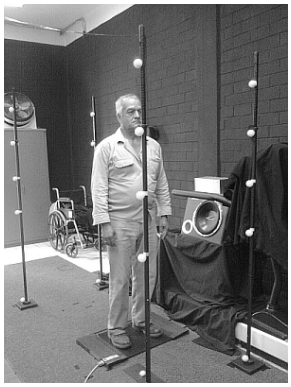


Induced infrasound waves as the perturbation stimulus

range 0.1 Hz to 5Hz directed to the hip of the subject for 30/30 seconds



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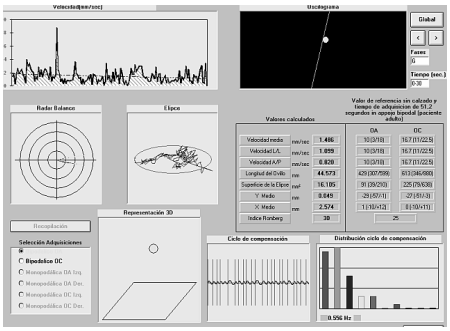
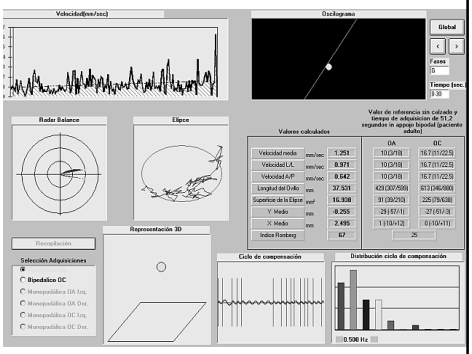
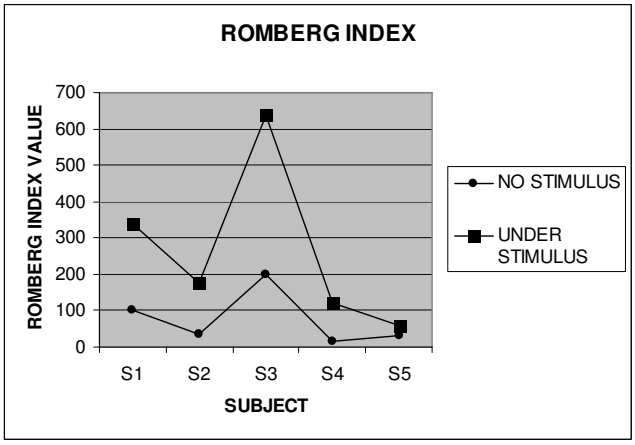
The Romberg index changed from 30 to 67 after the subject was submitted to the infrasound stimulation







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Discussion

As we mentioned before, stability was evaluated using a control theory criterion, which establishes that proximity of the roots of the second-order equation to the imaginary axis of the complex plane can determine how stable or unstable a control system is. This concept can be associated to the location of the poles corresponding to each group. Major proximity in 30-40 range of age can be observed and it can be related with mature systems that require facilities to perform faster movements without losing the equilibrium. Proximity is also related with more stability when this location is associated with the capacity to perform fast movements.

Contrarily, location of the poles corresponding to elderly is the most distant from the imaginary axis. These results represent not only a more unstable condition but also a limited potential for moving faster to avoid falls. Deteriorated systems in elderly results forwards to indicate that the risk of falling could be higher as farther the poles are from the imaginary axis in these cases.

The study is simple and short according with the limiting conditions required for young and elderly; fast for the former and easy and secure for the later, trying to overcome cognitive problems to follow instructions.

Given that from the analysis, several important parameters are obtained, a classifying strategy can be implemented in order to reinforce the potential for detecting the risk of falling.

As concern to the infrasound stimuli, even some changes in anterior-posterior velocity, lateral-lateral velocity and mean velocity of the center of pressure were observed, some references from people who have suffered falls are needed to establish a possible relationship between those parameters and the risk of falling.

Conclusions

The convergence of the correlated data acquisition with the typical answer of second order control system is encouraging to find a good indicator of risk of falling in elderly.

Mechanical stimulation waves allow us to observe destabilizing effects caused by artifacts in the environment, in this sense, elderly are the most vulnerable population to such events infrasound waves.

The Romberg index was used to detect differences in responses when normal or under stimuli conditions were present. In order to obtain an indicator of risk of falling using this technique, a major sample and more experiments are required.

A novel and objective method has been developed to detect the risk of falling in elderly based on the movements of the head when subjects are submitted to the visual stimulus-response technique. The method is comfortable, fast, and not invasive. Moreover, the method will allow the study of evolution of regulatory systems since early ages of children as well as trends of deterioration in elderly.

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