Stability Evaluation of the Elderly Using a Force Plate

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Abstract— **The maintaining of balance when standing is for a person of any age an essential requirement for performing common, every day functions, avocations and activities and for independent mobility. These listed aspects can be considered as primary criteria for evaluating quality of life. From statistical data, approximately one in three patients age 65 or older say that they fall at least one time each year, and 70% of all falls cause an injury to health. A broken neck of the thigh bone is among the most complicated and the most dangerous of these injuries. The purpose of this study is an evaluation of the measured parameters using a force plate as the main indicators for the assessment of stability of the human body when standing, which can be predictive for assessing the risk of a fall occurring.**

Keywords— **stability, senior, force plate, falls, rehabilitation.**

I. INTRODUCTION

Aging is an inseparable component of life, and maintaining balance when standing is for individuals of any age, but especially in old age, a necessary requirement for performing every day activities as well as for preserving independent mobility.

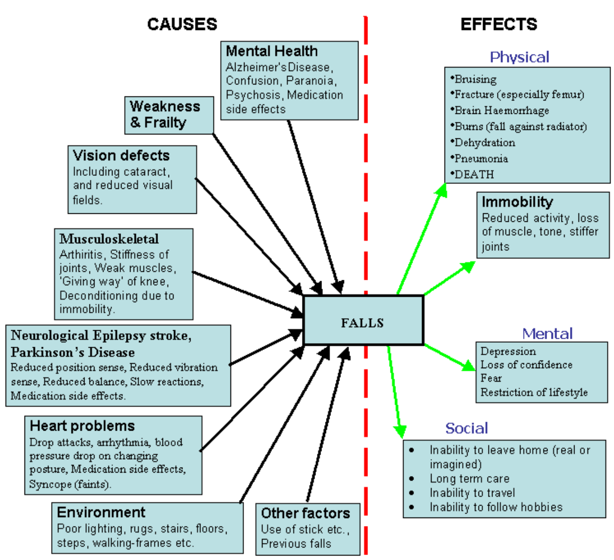

Fig. 1 Reasons for and results of falls.

According to the literature seniors older than 65 years are the most endangered by falls, an increase in falls is recorded with rising age and in 30% of cases these are repeated falls. The result of a fall can be morbidity and mortality but also a reduction in the quality of life; in 10% injury occurs to the head and soft tissues, and in 75% of falls the result is the fracture of a limb (with respect to osteoporosis they occur more often in women than in men). Falls of seniors lead to hospitalization and subsequently higher health care costs (Fig. 1) [1].

During the process of maintaining balance information from receptors (sight, the inner ear, proprioreceptors of the lower limbs and neck) is processed. The result of this process is the correction of movements altering the position of the centre of gravity. The centre of gravity of the body is associated with the stability of a person in individual stances and positions (Fig. 2). In the human organism the centre of gravity in the basic anatomical posture is located approximately at the height of the second sacral vertebra; in women this is perhaps 1-3% lower than in men.

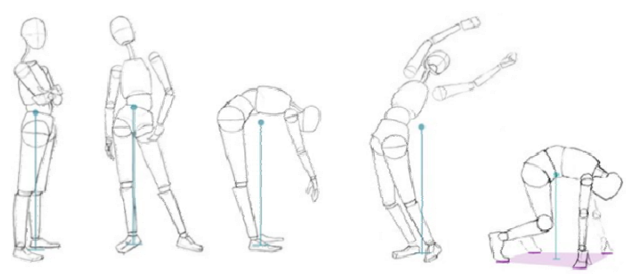

Fig. 1 The position with projection of the centre of gravity depending on posture.

Standing is the position of the body during which the main portion of the weight is transferred to the lower limbs and is cancelled by the pressure of the legs on the base. Stable standing requires a perfect interplay between the muscles that hold the stance, cancel out the working of the body's weight, hold the joints in the necessary position and compensate for deviations so that they maintain the body in a balanced stance. From a biomechanical point of view, standing is a very unsettled position, because the support

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base (the pedestal) is small and the body's centre of gravity is high above the base.

During stable standing it is important to hold the body's Centre of Mass (COM) in the vertical position above and inside of a certain restricted space on the base in the area of the soles of the feet, which is labelled as the Base of Support (Fig. 3).

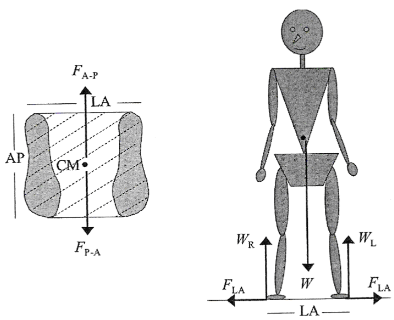

Fig. 2 Base of Support and working force. [2]

The conditions of static equilibrium are applied with difficulty in the case of human balance, because the human body is a "multi-segmented construction" [2]. This means that during each change of position of the limbs, head and torso, not only does the position of the centre of the relevant segment change, but also the position of the centre of gravity of the entire body. The position of the centre of gravity is crucial to the stability of the body [3]. In the ideal case the sum of all elemental forces of the individual body segments should amount to zero. However, in the case of human equilibrium of standing, a certain flexibility is allowed, namely such that movement of the COM is permitted horizontally and vertically within the scope of the base and without leading to the given person falling down.

One of the possibilities for evaluation of the stability of subjects during tranquil standing is measuring the centre of pressure (COP) in relation to the pedestal (the surface beneath the feet and between them). It is possible to measure COP exactly with a sensing system such as a Kistler force plate [4].

II. Methods

Measuring was performed on 27 selected seniors over 65 years of age from the Geriatric Centre in Košice, Slovakia, who were living in independent households. The selected group of seniors had to be capable of walking a distance of at least 20 metres independently, without the help of a personal assistant or a supporting device, the use of a walking stick was accepted so long as contact with the ground occurred only one time. Another criterion for being included in the group was the ability to stand for 90 seconds without help and one or more falls in the previous year, not including falls during sporting activities. From standard physical and cognitive functional tests the Tinetti balance test was conducted with the resulting score in the category of medium to low risk of falls. From the 27 subjects 24 seniors were included in the real measurements and 3 persons were considered to be replacements [5]. Participants in the measuring were volunteers informed in detail regarding the process of the testing. Among the criteria which excluded subjects from measuring were being classified as having a serious vision disability (a worsened ability to read, watch TV ...), a serious hearing disability (problems with following a conversation, with using the telephone, ...), electronic implants (cardiostimulator, cardiofibrillator ...) and other serious limitations, such as: muscle weakness or a palsy of the lower limb (e.g. inability to lift the feet from the floor), neurological disorders, including Parkinson's disease, multiple sclerosis, state after stroke, spinal diseases, Meniér's disease, serious cardiovascular diseases, problems with the feet, amputation of a lower limb, or disorders of the joints, terminal illnesses (defined as the estimated length of life at less than 6 months), legitimate pain.

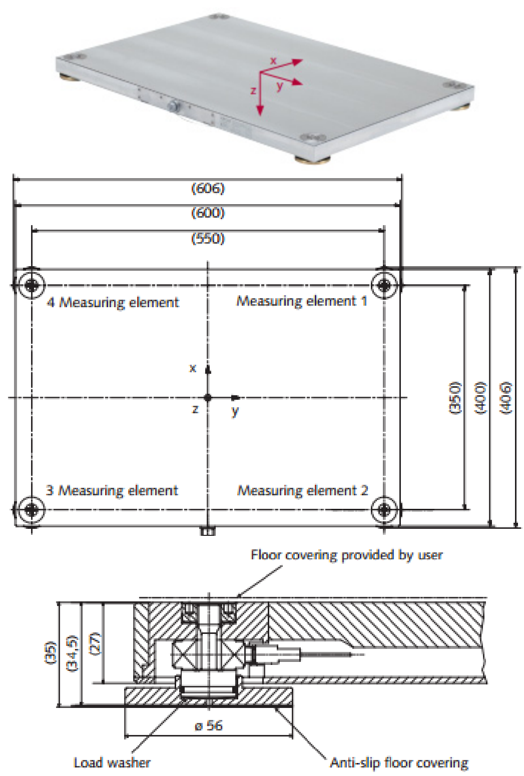

Fig. 3 Dimensions of portable multi-component force plate Type 9286B.

The measurements were carried out on a KISTLER type 9286B Portable multi-component force plate with an aluminium top plate for measuring ground reaction forces (Fig. 4), moments and the centre of pressure in biomechanics [6]. The piezoelectric 3-component force sensors have very low crosstalk values and in conjunction with the special design principle ensure excellent accuracy of the centre of pressure.

Software used: BioWare type 2812A.BioWare software is the engine behind the force plate system. It collects data from the force plates, converts the trials into useful information and plots the results. The force plates and charge amplifiers are fully remote-controlled by BioWare, thus making the system extremely flexible and easy-to-use.

The parameter evaluated was Change of velocity of movement of the COM in the mediolateral (ML) and anterioposterior (AP) directions, namely for the state with eyes open (EO) and closed (EC).

Measurement with the force plate was performed before training (T0) and at the end of training (T2). The first and second stage of training lasted 4 weeks, with a 1-week break. Within one stage of training, 8 exercise sessions were performed, 2 sessions each week lasting 30 minutes each.

III. MEASUREMENTS

Postural balance of the human body was assessed through the Kistler force plate on the basis of monitoring the parameters of the centre of mass – COM – as the predictive factors for assessing the risk of falls occurring.

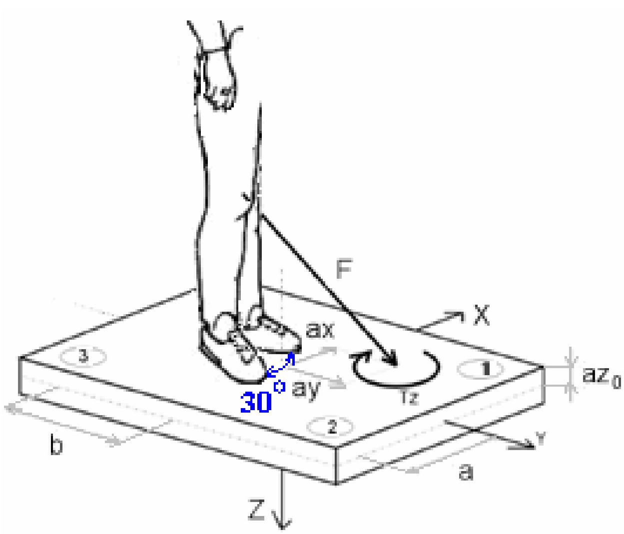

Fig.4 Measuring of postural stability (placing of the feet on the force place). [3]

The individual measurements were made in a stance with open and closed eyes for a period of 30 seconds. During testing the subjects were examined in an erect position with upper limbs hanging freely by the body. The stance was continuous, and the feet touched each other at the heels and the tips of the toes included an angle of 30° (Fig. 5). During the testing with open eyes the subject directed his or her sight on one arbitrary point to the front (at eye-level).

During evaluation of stability, the average velocity of movement of the COM in the mediolateral (ML) and anterioposterior (AP) directions was assessed. Since each measurement lasted the same time (30s), the velocity of movement of the COM corresponded with the length of the track which the COM overcame during the test.

IV. RESULTS

If during testing the use of vision is allowed, the subject acts as a pendulum, exploiting the inertia of the torso and head, and stabilizes the head in space thanks to perception of an exterior spatial reference point or object. If the use of vision is not permitted, the head oscillates in the anterioposterior direction more, and in this case a change in the weight of the body, the contracting of postural muscles and the holding of postural reflexes are needed for preserving balance.

During bipedal standing the average values of oscillation of the individual velocities of movement of the COM of the measured subjects in a mediolateral (ML) direction (the x-axis) were lower than the anterioposterior oscillation (the y-axis), which indicates better lateral stability of the subjects.

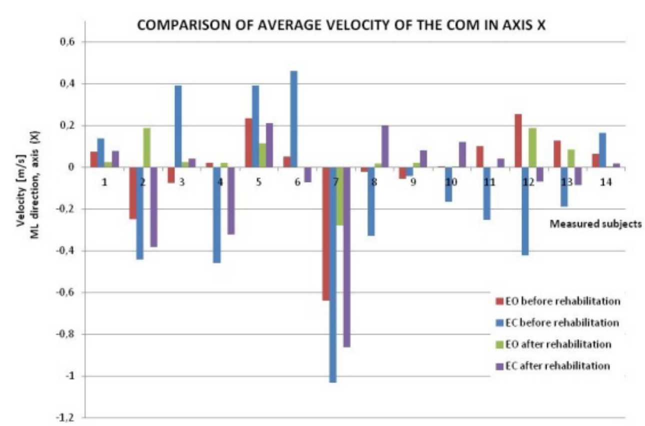

Fig. 5 Comparison of the average velocity of COM in the X-axis.

From comparing of the average velocities in a mediolateral direction (x-axis) it is obvious from the results of the measuring that during testing of the subject in the state with open eyes the values in the majority of measured subject are located near zero and in the state with closed eyes larger deviations occurred. Upon comparing the results before and after rehabilitation it is possible to state that the average value of the difference of deviations for measuring with open eyes is $0.071 ms^{-1}$ and with closed eyes is $0.165 ms^{-1}$ (Fig. 6).

From a comparison of the average velocities in the anterioposterior directions (y-axis) the values of the deviations of average velocities are higher than in the mediolateral direction. In the case of a comparison of results before and after rehabilitation in the anterioposterior direction it is possible to state that the average value from the difference of deviations for measuring with open eyes is $0.150 ms^{-1}$ and with closed eyes is $0.272 ms^{-1}$ (Fig. 7).

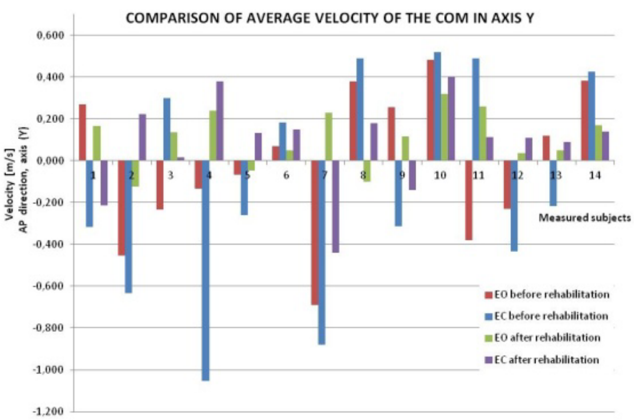

Fig. 6 Comparison of the average velocity of COM in the X-axis.

V. CONCLUSION

The results of the study according to Bekedorf point to larger deviations of the plane of the centre of gravity during tests with eyes closed, which is also confirmed by the conclusions of Brunnstrom's work relating to visual information, where he describes that a visual image of the positioning of the body and its parts in relation to reference points in the immediate environment offers supplementary information for the maintaining of balance. This theory is also confirmed by Duarte, who in his conclusions from the year 2000 states that visual information is important for modification and correction of position.

During tests with open and with closed eyes larger deviations were found in the forward-backward direction versus the sideways direction. Clapp and Wing (1999) confirm that the high values of AP oscillation during bipedal standing occur 2x more often than sideways oscillations, which suggests lateral stability. Hodges (2002) ascertained that predominate lateral oscillations indicate problems or a malfunction in the CNS.

On the basis of the demonstrated measurements of average velocity of COM in the mediolateral direction with eyes open after rehabilitation, it is possible to state smaller oscillations of gravity by 49.44%, and with eyes closed by 52.81%. From the measured values of average COM velocity in the anterioposterior direction after rehabilitation it likewise follows that smaller deviations occur in the centre of gravity with eyes open by 49.32% and with eyes closed by 41.73%. The results of the measurements of stability using the force plate likewise correspond with the above-mentioned studies, from which it follows that the disk is a suitable alternative for assessing balance as a primary indicator for assessing the risk of possible falls occurring.

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CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

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