Evaluation with stabilometric platform of balance disorders in osteoporosis patients. A proposal for a diagnostic protocol

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Summary

Osteoporosis is a systemic disease with reduced bone mass and qualitative alterations of the bone, associated to increased risk of fracture. Pathogenesis of osteoporosis fractures is multifactorial. Main risk factor is falls (except for vertebral fragility fractures which occurs often in absence of trauma). Aging by itself produces physiological changes: muscular hypotrophy with asthenia, deficit of visus and hearing together with associated pathologies and multi-drug therapies. In osteoporosis patients with vertebral fractures posture change occurs which reduces balance. After clinical postural evaluation it is possible to carry out instrumental evaluation of posture with computerized methods such as stabilometry, baropodometry, dynanometry and gait analysis. Examination carried out with use of stabilometric computerized platform allows stabilometric (body sway assessment) as well as posturometric examination (center of pressure assessment during quiet standing). Fundamental parameters obtained are: position of the body center of gravity, area and shape of sway density curve and velocity variables. Protocol of evaluation includes assessment of examination in standard condition and in condition of temporary sensorial deprivation (to investigate the influence of various afferent systems on the maintenance of posture and balance). Accurate evaluation of postural control in osteoporosis patients constitutes a fundamental tool in fracture risk evaluation due to fall and in identification and correction of modifiable factors responsible for balance defect. This approach, together with adequate drug therapy, may lead to significant reduction of fractures in osteoporosis patients with subsequent reduction of hospitalization and residual consequent disabilities.

KEY WORDS: osteoporosis fractures, fall prevention, stabilometry.

Introduction

Osteoporosis is a systemic disease characterized by reduced bone mass and by quality characteristics of the bone (macro and micro architecture, material properties) and is associated with an increased risk of fracture.

The ESOPO study (1), an extensive epidemiological study carried out in 2001, indicates that almost 23% of women over 40 and 14% of men over 60 have osteoporosis. It is estimated that at present in Italy over 3.5 million women and 1 million men are affected with the disease. Main complications related to this pathology are represented by fractures, both spontaneous and associated to minor trauma, which involve various districts of the osteo-articolar system. In fact, the US trial study of osteoporosis fractures (SOF) has evaluated prospectively if a low femoral bone density is predictive of a fracture in the same site. The study has shown that the reduction in standard deviation in age (z score) increases the risk of fracture by 7 times compared with the control group (2).

Among fragility fractures in the first position for incidence are fractures of proximal epiphysis of the femur, vertebral fractures and wrist fractures. In women the most affected site is the vertebral column (35%) followed by hip (17%) and wrist (16%) whereas in men the percentage of fracture is 6% for hip, 5% for vertebral column and 2,5% for wrist.

The Italian osteoporosis league has recently elaborated an estimate of the overall economic impact of osteoporosis fractures which, only as regards hospital expenses, amounts to 12 billion euro yearly in USA and 3,5 billion euro in Europe. These data confirm that osteoporosis (particularly the associated fragility fractures) have a considerable impact on morbidity and mortality for millions of persons especially in terms of health and social expenses (hospital admission and treatment for residual disabilities).

The pathogenesis of osteoporosis fracture is multifactorial. Espallargues et al. have identified almost 80 risk factors for osteoporosis fracture. Nevertheless in the above study only 15% of them presented a relative risk higher than 2 (3).

With the exception of vertebral fragility fractures, which happen frequently in the absence of trauma and are not recognized in over 50% of cases, the most important risk factor for fracture in osteoporosis patients is due to falls. It has been estimated that almost 30% of subjects over 65 experience a fall every year and at least 20% need medical care following trauma (4-6).

In order to understand the causes of the increased risk of fall and therefore of fracture in osteoporosis subjects it is necessary to clarify the concepts of posture and balance. Posture and balance maintenance are the result of a complex cybernetic system defined as postural tonic system which articulates at 3 different levels. Information coming from the external environment is captured by periphery receptors and elaborated in real time at the level of central nervous system (sensorial-motor cortex, nuclei of the base, thalamus, cerebellum, encephalic trunk and spinal cord) in order to trigger through efferent structures (skeletal muscles and muscular chains) a correct answer to external stimuli of balance changes. Receptors through which information reaches the central nervous system are numerous. Most important are the vestibular, visual, stomatognathic and exteroceptive systems through the plantar aspect of the foot. Furthermore postural information can reach also through muscles, joints, skin and the interoceptive receptors. It is well known that aging by itself produces a series of physiological changes such as muscular hypotrophy with weakness, reduction of sight and hearing, each of which represent a risk factors for falls. Furthermore elderly subjects frequently have several pathologies: Parkinson's disease, periphery neuropathies, arthropathies, depression, orthostatic hypotension and cognitive deficit may interfere considerably with posture and balance (7). Also multiple drug therapy can be responsible for a balance reduction. In fact according to recent studies there is a clear correlation between falls and daily intake of 4 or more drugs, although the risk associated with individual classes of drugs is variable. The risk of falls appears to be higher in elderly people who make use of neuroleptic, benzodiazepine, tricyclic antidepressant, selective serotonin reuptake inhibitors (SSRIs), anticonvulsants and antiarrhythmic agents of class 1A (8).

In the elderly there are modifications of posture which can lead to deficit of balance and therefore increase the risk of fall (9). There is ample evidence that the elderly make greater use of the hip mechanism (less accurate and less effective than the ankle mechanism) in reply to the external balance disturbances. Furthermore in elderly subjects with osteoporosis vertebral fractures (often multiple), if not properly treated, this may lead to progressive increase of dorsal kyphosis which displaces forward the center of gravity exposing the subjects to an increased risk of fall, hence to an increase of the risk of fracture and permanent disability. Dorsal kyphosis is frequently related to a reduction of physiological lumbar lordosis leading in extreme cases to total kyphosis of the spine. The latter compels the subject to pelvis retroversion and to hips and knees flexion. In the elderly this altered posture causes a greater energy expenditure with quick tiring of the subject and worsening of the physiological deficit of balance.

There is limited evidence in current literature on the evaluation of balance deficit with computerized methods (stabilometric platform, dynamometric or gait analysis). According to Ishikawa et al. (10) there exists a positive correlation between lumbar lordosis, anterior inclination of the column with subsequent postural instability and increased risk of fall. Termoz et al. (11) with evaluation on dynamometric platform have demonstrated that the ankle mechanism is more frequently used by younger subjects and is more accurate, whereas the hip mechanism is more frequently used by the elderly and is less accurate. Furthermore the authors suggest that patients with Parkinson's disease have a mixed posture control mechanism (hip and ankle) probably due to the muscular rigidity and to the flexed posture. This reduces the postural stability with subsequent risk of fall. According to Viljanen et al. (12) deficit of hearing causes an increased risk of fall which is partially explained by deficient postural control. Also visual deficit if associated with other sensitive deficits (hearing or balance) causes an increase in the number of falls for reduction of compensatory neurological mechanisms (13). A recent study (2009) carried out with stabilometric evaluation has shown an increase of the area drawn by the center of pressure (COP) sway in the elderly compared with the young due to an increase in the width of body oscillations with postural instability (14).

For the evaluation of sensorial receptors which disturb posture there is particular indication to stabilometric platforms even if a deep analysis of the postural tonic system from pressure and dynamic point of view requires the use of baropodometric and dynamometric platforms. In our outpatient clinic postural investigation is carried out with the stabilometric platform Lyzard® which is provided with piezoelettric transductors capable of identifying the vertical component of the forces exercised on the same platform thus making it possible to measure the COP of the foot-bearing surface. Therefore with the use of the stabilometric platform it is possible to evaluate the change in time of the center of gravity and its oscillations in the course of data uptake (stabilometry). Furthermore it is possible to identify the loading on the plantar supporting surface (posturometry). The COP represents the point of application of the result of forces exchanged between foot and ground that is to say the center of gravity of binding reactions to the ground applied at every point of the foot surface in contact with the loading base. The parameters which can be obtained from this type of analysis are many but the fundamental ones are the position of the body center of gravity, area, shape and proportion of shape of the COP sway, its variance and velocity.

The COP area is an index of the effectiveness of the tonic postural system in keeping the center of gravity closer to the intermediate position of balance. Normally the COP area is bigger during the test done with closed eyes up to 250% as compared to the test done with open eyes. If in a subject there is a very marked increase of the COP area when the eyes are closed and a great expenditure of energy when eyes are open it means that there is an exaggerated postural visual control. This aspect is typical of elderly subjects without focal neurological deficits, who are subject to frequent falls which cause great anxiety while walking or standing, particularly in non familiar places while trying to compensate with visual afference (conscious). On the contrary, in the elderly subject who has no fear of falling there is considerable lowering of visual participation in postural control. Reduction of the COP area is associated with an increase in spinal or generalized muscular rigidity, neurological defects or emotional disturbances. For example a dot-like bundle area in subjects that have body instability, if associated to great expenditure of energy (high velocity variance) may indicate an automatic postural hyper-control, i.e. a muscular hypertone particularly spinal, which materializes frequently following cranial or vertebral trauma. The form expressed by oscillation is also very important. In normal subjects the COP area has a slightly ovoidal shape with major antero-posterior axis while body sway is harmonic. A very wide COP area when eyes are open, which becomes bigger in assessments done with eyes closed with harmonic body sway is frequently an indication of an exaggerated voluntary postural control. On the other hand a star shaped very wide COP area (sudden inversions of the direction of the COP) which remains stable in all testing conditions suggests a neurological problem.

Velocity variance expresses the relationship between accelerations and decelerations during oscillations. The higher the variance the greater is the discomfort and the energetic loss to the patient. A patient in balance moves slowly and has low variance, while the patient with pathologic posture has a non-fluid movement and a higher variance. Furthermore variance allows to evaluate if the corrective intervention is more or less effective: in fact the return of other parameters to normal values after correction indicates the effectiveness of the correction on condition that variance remains low, otherwise the compensation leads to higher energetic expenditure which is of no benefit to the patient.

It is important to underline that the correct evaluation of the patient must take into consideration such parameters collectively (and not as an absolute value) as a variation of the assessed values in the single subject because principal conditions of data uptake may vary during the test.

In the test protocol adopted data uptake of the examination was done in the following conditions: opened eyes and clenched teeth, opened eyes and unclenched teeth, closed eyes, open eyes with unstable surface (foam pillow), closed eyes with unstable surface. To these conditions it is possible to add, as required, other particular conditions depending on the single case under examination. The standard condition is represented by the assessment with open eyes and clenched teeth, conditions in which all the external afferences are active and the parameters previously described reflect the postural control of the subject under examination. The assessments that follow are carried out with temporary sensorial deprivation in order to exclude in each test a specific receptor afference and therefore to evaluate its influence on the tonic control of the subjects posture. With closed eyes (visual afference eliminated) in the healthy subject normally it is possible to observe an increase of the COP area equivalent to almost 250% of the bundle area measured with eyes open. If there is no increase in the COP area in assessments done with eyes closed or if there is increase lower than 100% it can be concluded that the visual afferences are not utilized in the maintenance of postural control and that they can actually disturb with such control. Visual imperfections such as myopia and astigmatism, particularly if there is a marked difference between the two eyes can interfere considerably with the postural control. This may occur when there is inadequate correction of such defects or inadequate position of the spectacles. Therefore in spectacle bearing subjects, standard assessments must be done with and without spectacles and compared with assessments done with closed eyes.

Assessments done on unstable surfaces eliminate exteroceptive afferences of the plantar aspect of the foot making it possible to underline how much plantar-irritation causing conditions, defects of plantar weight bearing surface or sensitive deficit (as in the case of subjects with diabetic neuropathy) interfere with the balance control. All soft plantar soles cause reduction of stability in normal subjects and increase the surface of the statokinesiogram. In such a situation of sensorial deprivation the subject relies on increased importance of vision. Alteration of the plantar bearing such as the pes cavus, pes valgus pronatus or pes varus supinatus cause a reduction of ground contact up to a real sensorial deficit. In these cases the use of heat-formed personal foot orthoses allows the participation of a greater number of plantar mechanoreceptors and improves postural control.

Assessment done with eyes closed while standing on an unstable surface (foam pillow) allows measurement of effectiveness of the vestibular apparatus: subjects over 60 are able to compensate rather well a deficit of afferences of a single system of entrance but compared with young subjects postural control is reduced notably if the sensorial deprivation involves simultaneously visual and plantar afferences (14). In subjects with vestibular pathologies (Labyrinthine Dysfunctions, Ménière's disease) assessments done in double sensorial deprivation show marked alterations of all the evaluated parameters. Finally assessment done with unclenched teeth investigates interferences related to stomatognathic apparatus.

It is important to underline that stabilometric examination (an important aspect of an accurate clinical examination of the patient) is not a diagnostic examination, but it provides an indication on the basis of which it is possible to address a subject to specialist tests in order to cope with the multidisciplinary problems of the osteoporosis patient.

In conclusion, although in literature contrasting data are reported on the role of stabilometric analysis as a diagnostic tool it is believed that an accurate evaluation of the postural control in osteoporosis patients represents a fundamental tool for the evaluation of the risk of fracture due to fall. Together with a correct diagnosis of osteoporosis and a correct drug therapy to avoid fracture, identification and correction of modifiable factors responsible for balance defect could lead to a significant reduction of fractures in osteoporosis patients with subsequent reduction of hospitalization and of residual consequent disabilities.

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