

## Review Article

# Proprioception and Aging

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Maintaining balance and postural control is of central importance for the older adults, since it is associated with falls and subsequent health problems. The onset of mobility impairments is usually assessed by checking for limitations in daily activities, underlying to importance of further evaluation. Calculation of proprioception is based on tests assessing the level of somatosensory functionality, by using balance and gait tests and through the single limb postural stability test. Functional evaluation is carried out by several means, such as the Get up and Go or Functional Reach tests, the Tinetti Balance and Mobility Scale, the Berg Functional Scale, the Sensory Organization Test and the Instrumental Activities of Daily Living Scale. Many interventions lead to positive effects, such as physical exercise, balance training, empowerment or strength training, combined balance and strengthening training, general exercises, tai chi. These interventions improve balance, enhance balance mechanisms of the older adults, lead to improved physical health and better mental health. Thus, it is of most importance for health professionals to use evaluations for proprioception in the older adults and to apply subsequent interventions.

**Keywords:** Assessment, Functional evaluation, Older adults, Proprioception, Third age**Introduction**

It is essential to determine whether a symptomatology is due to normal ageing or a consequence of progressive decline in physiological function, observed in older groups<sup>1,2</sup>. The processes of recovery and disease play a key role in the manifestation of physiological changes along time<sup>3,4</sup>. The progressive decline of the basic systems of the human body contributes to the manifestation of weakness, as well as fatigue and impairment in various movements that limit an older person's ability to perform various daily activities or physical activity<sup>5</sup>.

**The importance of balance and postural control**

A variety of studies have demonstrated that altered balance is an element linked to the occurrence of falls that lead to reduced mobility or independence in functionality. Modifications in balance capability result as a consequence of illness and ageing. There are also findings showing that age-dependent changes occur in the three sensory systems

(vestibular, ocular and also the somatosensory system)<sup>6</sup>.

The concept of orthostatic control lies in the capability to sustain balance in gravitational areas: maintaining the centre of mass of the body against the support centre of the body<sup>7</sup>. During conditions of stress, orthostatic control is inflated particularly in the older adults<sup>2</sup>. Postural stability is affected by changes that take place in the sensory and motor systems, as well as the perceptual system<sup>8</sup>. The older adults experience a reduced adaptive capability in balance and orthostatic control<sup>9</sup>. Any unexpected disruption of the support surface triggers automated postural control

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responses in somatosensory, involving firstly an activation of the distal leg muscles and subsequently of more proximal body muscles, reinforced by ocular and vestibular stimuli<sup>10</sup>.

Neurophysiological, balance involves the interaction of vestibular, somatosensory and ocular system sensory information. The vestibular system gives the energy needed to support the head against the power of gravity. The somatosensory system gives information regarding the movement of different parts of the body. The ocular system gives information regarding body's position related to the environment<sup>6</sup> and consequently those visual stimuli affect beneficially the proprioceptive feedback to the muscles<sup>11</sup>.

Several studies have investigated specific characteristics among adults at younger and older ages<sup>12,13</sup>. Adults in later life show:

1. Reduced response to loss of balance and repair after injuries since latency of the anterior tibialis muscle exists.
2. Increased frequency of spinal monosynaptic reflexes, with a limited latent period of manifestation when subjected to surface rotations.
3. Muscle weakness of the dorsiflexor ankle flexor (key agent in dysfunctional balance).
4. Increased variability with respect to the ratio of the range between proximal and distal muscle activity.
5. Hip movement strategies versus loss of ankle swing, in answer to unexpected perturbations.
6. Non-physiological sensory selection, often resulting in excessive use of vision or minimal use of proprioception.
7. Alterations regarding the perceptual limits of stability, resulting from a reduced sense of optimism.

### The importance of functional balance in the older adults and the effects of aging

A normal gait needs mobility of the joints, proper timing, strong contractions of the muscles as well as physiological proprioceptive, ocular and vestibular sensory signals. The older adults often demonstrate alterations resulting from dysfunction in one or more of the above leading to imbalance, increased energy expenditure, muscle weakness and episodes of falls. Research carried out by Tang & Woollacott (1996) showed that in people aged over 75 years, 30% reported difficulty in climbing the stairs, another 40% could not travel a distance of more than half a mile and 7% needed assistance with walking. Bedridden or confined to a chair persons have a high risk to develop swelling, contractures and wounds as a result of changes in blood pressure<sup>10</sup>.

The onset of mobility impairments in older people is usually assessed by checking for any limitations in daily activities (e.g. dressing, bathing). Although in most cases the motor disabilities in question are due to a progressive decline in the function of neuromuscular and musculoskeletal system, they may quicken in cases of trauma<sup>14</sup>. Voluntary mobility can be assessed and categorized as basic, expanded and extreme. When someone sits in a sofa or chair is an

example of basic mobility. Stretching to reach a high object is an example of extended mobility. Performing sports or dance are both cases of extreme mobility.

Although our understanding of transitioning from a functional independence to a physical weakness is limited, widely accepted is the fact of physiological dysfunctions that can compromise an adult's degree of independence of movement in later life. Simultaneously, their reduced functionality creates problems of participation in functional mobility activities or physical activity plans; it thus leads to the decline of quality of life through a continuous deficit in independence and purpose in life itself<sup>15</sup>.

Sarcopenia is related directly to a reduced mobility and physical performance in addition to an increased percentage of accidents to which people with muscle weakness and poor balance are prone to<sup>16</sup>. Muscle strengthening is associated with the ability to walk, or climb stairs, or transitioning from sitting to standing<sup>5</sup>. The number of adults in old age whose functional ability is at extremely poor levels is very high, needing assistance for simple activities or personal hygiene<sup>17</sup>.

Skill performance dysfunctions dependent on age become furthermore apparent at increased speeds of mobility. Since a lot of activities in everyday life demand dynamic movements, whereby force is required to be channeled into the muscles (e.g. climbing stairs), cases where a reduced ability to channel that kind of a force is recorded need special attention and treatment<sup>16</sup>.

A systems approach assists to recognize any subsystem that has a significant impact to the reduced ability to ensure balance control, though if a single subsystem is reduced, it is extremely difficult to identify through the numerous compensatory mechanisms of the ensemble<sup>8,10</sup>. Numerous alterations are drawn in the gait of the older adults, including reduced walking speed, recorded most strongly in cases of older adults with limited activity and additionally strongly in cases of hospitalized due to a fall<sup>2</sup>. A notable association exists between a muscle endurance and the optimum speed of walking in the third age. Lower extremity strength may be the predictor of functional activity, as it is a more representative way of dynamically recording muscle function<sup>9</sup>.

### Calculation of proprioception using subjective criteria

Proprioception is closely related to the concepts of stability and neuromuscular performance<sup>18</sup>. Functional estimation of the ocular, peripheral and vestibular combined contribution to the modulation of myofascial control is achieved through balance assurance and measurements of orthostatic oscillation of the lower limbs<sup>19</sup>. Therefore, an in-depth balance assessment should incorporate an assessment of lower sensory levels.

1. At the level of somatosensory functionality, the respective tests should include items that touch on the investigation of the skin sensation of leg functionality, as

well as proprioception in the foot and ankle regions.

2. Balance and gait tests should include scenarios in which the sense of sight is not available and should be applied to different types of surfaces<sup>8</sup>.
3. The test of single limb postural stability is a technique often used at the proprioception level of the knee region, involving afferent knowledge about the ocular and the vestibular systems, in conjunction with abstract motor features<sup>20</sup>.

Equilibrium is often utilized in the assessment of functional joint stability, with deficits resulting from the progressive depletion of proprioception in the limbs<sup>17</sup>. Inability to maintain unilateral orthostatic balance is associated to an increased degree with functional instability of the joints. Studies imply that lack of equilibrium in persons with a previous functional joint instability is an indication of proprioception deficiency in knee region<sup>21</sup>.

The increased degree of variability between the different methodologies applied in proprioception assessment prevents any direct comparison in the context of different studies<sup>21,22</sup>. The ideal methodology should be governed by increased levels of sensitivity and specificity, while at the same time being characterized by adequate repeatability and accuracy<sup>20</sup>.

## Functional evaluation

The existence of a functional assessment system can be a reliable indicator to identify older people with difficulties in managing daily functional activities and therefore at increased danger of falls<sup>23</sup>. Direct observation, combined with performance measurement in daily motor functions, the performance of which requires static and dynamic balance control in different spaces, provides the opportunity to identify problems related to balance control<sup>6</sup>.

The findings of functional assessments may show the necessity for treatment and at the same time act as a criterion for subsequent assessment during training/evaluation of the subject. There are different types of tests through which functional balance is measured in relation to the control of the postural position. In addition, it is suggested to collect information regarding the number and type of falls, as well as near falls that take place<sup>24</sup>.

The test of Get Up and Go is a rapid screening process to identify difficulties among the population of the third age<sup>6</sup>, yet not to record any possible individual changes in functionality. The Up and Go test, to which the time parameter has been added, showed that adult cases with no neurological symptoms and independence, in terms of balance and motor skills, completed this test in 10 seconds at most. All the participants that needed over 30 seconds of time, were characterized by dependence in the majority of their quotidian activities and motor skills, respectively<sup>23,24</sup>.

Mobility assessment tests focus on the quantification of mobility, in which the patient's ability to perform a specific skill is examined<sup>12</sup>. The test of Functional Reach was formed

by aiming at the analyzation of the older adults's capability to sustain equilibrium. The Tinetti Balance and Mobility Scale is a tool for testing balance and motor skills in adults in advanced age and for determining the possibility of falls<sup>25</sup>. Tinetti et al. developed a mobility score, in which they incorporated the parameters of gait and balance for pointing out cases disposed to falls with acceptable reliability and promising due to findings from balance assessment studies<sup>6</sup>.

The Berg functional balance rating utilizes 14 items, which are scored from 0 to 4<sup>6</sup>. This examination may present adequate reliability, although no control points have been reported to date<sup>23,24</sup>, yet it lacks a quantitative assessment of fall risk. However, it is accepted that a score greater than 45/56 is indicative of an extremely reduced fall risk<sup>12</sup>.

During the test of Sensory Organization, the person is subjected to six different sensory situations and should keep an upright position for a time of half a minute, the therapist notices any potential switches of the patient related to the amount and direction of the orthostatic oscillation in 5 different conditions. In case a patient is not able to hold an upright position for half a minute, a following test is performed<sup>26</sup>. Young adults, in absence of neurological signs, do keep their steadiness in the six different states of the test. When the number of falls is two or more, it is indicative of a difficulty in adapting the sensory information needed to achieve orthostatic control<sup>7,24</sup>. At the point of removal of this somatosensory data, systems as vestibular and ocular are evidently influenced<sup>26</sup>. Functional mobility as well as static equilibrium present a noteworthy association, when analogous sensory environmental circumstances are applied. The findings suggest that dysfunction of neurosensory balance control abilities possibly affect the achievement of functional mobility in third age<sup>10</sup>.

The ability of standing on one leg decreases while aging, hence when the study uses older people it is reasonable to set intervals of half a minute<sup>6</sup>. Oscillation is a satisfactory index of equilibrium, thus an increase in oscillation suggests loss of equilibrium power<sup>24</sup>. Walking test for six minutes is an encouraging measurement to investigate functional training ability regarding patients with congestive heart disease<sup>27</sup>. In addition, maximal oxygen uptake is a predictive indicator of exercise capacity in healthy women in advanced age<sup>2</sup>.

The test of Senior Fitness ("Fullerton Functional Fitness") was formulated by Rikli & Jones (2001). One end included participants in good physical fitness and the other end participants with weaknesses in physical fitness, respectively. This test has been used successfully in South Africa<sup>15,28</sup>.

Lawton & Brody created a scale, called Instrumental Activities of the Daily Living, in order to determine subject independence<sup>29</sup>. The range of these activities is necessary in order for a participant to ensure self-care independence in a restricted environment (e.g. using the toilet) or skills necessary for a community member to function (e.g. shopping). Recording dysfunction in these activities is

implied as identifying risk factors for falls and admission to health care facilities<sup>12</sup>.

## Interventions for proprioception in the older adults

### The consequences of exercise on the third age

Initiating physical activity with a moderate degree of difficulty is associated with reduced death rates, while reducing the percentage of falls or the injuries related to them, respectively<sup>15</sup>. The study by De Vries & Housh (1994) showed that healthy people aged 70 and 80 years have the same relative fitness for exercise as their younger counterparts. Insufficient physical exercise remains an autonomous prognosticator of reduced mobility<sup>4</sup>. Various exercise training programs improve functional independence of older people by enhancing their movability<sup>2,26</sup>.

### Stability education

Frailty or instability could be improved and even reversed after physical exercise and stability education<sup>2,26</sup>, with static and also dynamic type of exercises. The degree of difficulty increases as the speed or duration of the exercise increases<sup>30</sup>. The combination of balance and muscular exercise can reduce the frequency of falls<sup>31</sup>. Restoring balance helps people to understand other sources of sensory information in order to use them<sup>8</sup>, while improving their overall response is indicative of an improvement in orthostatic stability and at the same time a reduction in the probability of falls among older persons<sup>9</sup>.

Shumway-Cook & Woollacott (1995) demonstrated noteworthy improvement in people following balance exercise against control participants. More specifically, the group receiving the training showed significant improvement in five of the eight training conditions. Changes in muscle response characteristics were noted<sup>24</sup>.

In 2000 Rose & Clark conducted an analysis utilizing the ecological theory and its principles about perception as well as control. Participants were people of advanced age who have suffered falls in the past and followed two balance training periods (45 minutes each) on a seven-day basis, for a total of eight weeks. Findings suggested that interventions focusing on the implementation of specific activities are not the only way to perform daily activities, as it is necessary to improve postural control<sup>23</sup>.

In conclusion, balance training programs mainly focus on propulsive movement and activities involving endurance and speed while other activities include movement, jogging, aerobic dance and calisthenics exercises, which are also part of balance training programs<sup>26</sup>.

### Empowerment training

Older people who are physically fit have better motor control and synchronization than those with sedentary lifestyle<sup>2</sup>. A successful technique to improve requirements

of energy, reduce weight yet sustain a metabolically active tissue mass is by strength training<sup>9</sup>. Masdeu et al. reported that the implementation of a combined resistance and walking program contributed to a maximum possible walking speed<sup>26</sup>. Fiatarone et al. manifested that muscle strengthening in the leg region, to improve equilibrium, contributed significantly to muscle strengthening and to a reduction in distance covered in a walking mode<sup>32</sup>.

The strength factor may be more important than endurance for daily functioning and fall prevention. In the older adults, eccentric-type contractions are required for hypertrophy and improved neurological activation strategies, yet are associated with greater muscular workload. Meanwhile, the exclusive use of eccentric training leads to increased concentric and eccentric strength of the dorsiflexor region of the ankle flexor, yet application of concentric training for 8 weeks brought no additional gain<sup>33</sup>.

A study involved 100 inmates in a nursing home facility, who both had an initial gait speed of 0.46 m/s and who were categorized into control grouping and one of resistance exercise. Participants were additionally separated randomly to taking dietary substitute or placebo. After 10 weeks, an improvement of 0.05 m/sec was recorded for the grouping undergoing the strengthening program, but not for the control grouping or those receiving dietary substitutes<sup>26</sup>. A further study investigated the range of potential advance in the status of functionality (highlighting balance and gait parameters) as a result of advance in physiological status (highlighting aerobic and endurance parameters). Major purpose of this research remained to ascertain all differential health benefits of the various types of exercise tested<sup>34</sup>.

Strength training, moreover to the benefits in terms of action of insulin, density of the bone, metabolic energy, functional level, is also essential in increasing physical activity levels among older people. Levels of spontaneous activity did increase in older adults, as well as frail older adults, following an increase in muscle endurance<sup>9</sup>.

### Combined equilibrium and strengthening exercise

In 1993 Judge et al. integrated a 12-week program of highly intense isotonic resistance and equilibrium exercise to establish whether its application improves gait speed. Hip abductors, extensors and flexors, ankle dorsiflexors and knee extensors were tested. Lateral and front-posterior weight shifting, postural alignment as well as tai chi were involved. Important positive effects in muscle endurance and gait speed had been recorded, especially to participants with the shortest walking times at the start of the study<sup>35</sup>.

Older women choosing active lifestyle recorded less orthostatic sway, compared to peers choosing a sedentary lifestyle. Balance control is a highly complex concept, with the result that any benefits of an exercise program are a result of separate dysfunctions and kind of exercises applied<sup>2</sup>.

In a study of nursing home inmates, it is shown that



both the usual walking speed and the maximum walking speed were improved following a combined protocol<sup>26</sup>. In the same year Campbell et al. related the implementation of combined home-based equilibrium and strength exercise programme to significantly decreased falls and injuries in women aged over 80 years old<sup>34</sup>. The most successful documented interventions include simultaneous progressive strengthening balance training exercises<sup>9</sup>.

A combined proprioceptive rehabilitation protocol has also been proven to be:

- 1) beneficial via virtual reality designs, M.R.I. stimuli, brain imagery tools e.t.c. all of which attest the involvement of bilateral proprioceptive mechanism in all older adults<sup>36</sup>, even those institutionalized<sup>37</sup> and
- 2) way superior to vestibular focused rehabilitation, since on what refers to falling risk, the older adults present a centrally originated (rather than peripherally) sensory decline, ascribed to a sensorimotor imbalance between the two cerebral hemispheres<sup>38</sup>.

## Strength training

Professional athletes have better level of balance control on both functional and clinical checks. Older people who are in good physical condition demonstrate similar patterns of muscle activation to younger people. Frequently sustained physical activity is expected to bring about improvements in balance, as it provides day by day challenges and chances to develop balance mechanisms<sup>39</sup>.

A 12-month randomized trial compared the effect of a strength and endurance training program with an equivalent flexibility program. In the first case there were benefits in terms of cardiovascular fitness, strength, endurance, self-esteem and energy consumption, parameters in which reduced measurements were recorded for the second program implemented. On the other hand, the implementation of the second program was associated with reduced daily pain, in contrast to the first program where increased measurements were recorded. An optimal exercise program combines the parameters of flexibility as well as endurance and strength<sup>33</sup>.

Prolonged endurance training advantages involve lower coronary artery disease mortality, an improvement in body weight and blood pressure control (to those taking or not medications) higher aerobic well-being, better levels in lipids and extended by two years life expectancy<sup>2</sup>. However, this type of exercise has not been associated with benefits in terms of strength or muscle mass, yet the use of a combined strength and resistance program had as result a greater improvement in strength, compared to a similar program based solely on resistance<sup>33</sup>.

## General exercises

It is a fact that the older adults have difficulty in planning new movements (altered way the motor control systems work), need additional time to process neurological information, progress more slowly in the utilization of a new

skill and require more time to adapt to limited changes, maybe because of insufficient mobility, as well as encouragement in processing additional activities<sup>40</sup>.

Movability dexterity for people in later life (e.g. proprioception, balance skills) has been proven to bring about significant improvement<sup>9</sup>. One study with 100 people highlighted that after implementing a home-based exercise programme for 10 weeks, improvements in strength, walking speed, motor activities and self-esteem in the ability to avoid falls, respectively, were recorded<sup>1</sup>.

Several researchers have studied the potential correlation between aerobic well-being, grip strength and postural control. Increases in postural control may indicate a deterioration of the neurological system, which cannot benefit by resistance training. A study in which a 12-week exercise program was applied to women aged 72-92 years indicates that the main objective of increasing the participants' postural stability was not achieved, although an improvement in physical fitness was recorded<sup>39</sup>.

Pliability diminishes along aging, thus heading to movability together with joint stability loss. A particular correlation exists linking movability into an environment as well as the range of mobility following knee flexion, hip flexion and bending and the capability of taking on activities that require using arms or hands, respectively<sup>2</sup>. Improving the flexibility of various interventional exercise programs has as major principal that the properties of muscle and connective tissue are likely to ameliorate, joints pain is likely to lessen, while various patterns of muscular activation may alter too<sup>9</sup>.

Amongst various studies conducted to assess the risks arising from the occurrence of falls, some have used multidimensional programs. These programs were designed to include strengthening exercises and were individualized for each one of the subjects. Other studies did emphasize weight training, applying generalized programs to all participants. They resulted that improvements in balance and movability were recorded, but it becomes difficult to assess the nature of these protocols, especially in terms of delineating an exact number of exercises needed to achieve the expected outcome<sup>41</sup>.

## Tai Chi

Originally practiced by Chinese older adults people, it involves internal and external slow paced intervening movements, postural alignment, axial rotation of the body's torso while walking towards a narrower base of support, enhancing proprioception and overall wellness. Meanwhile it strengthens the immune system, improves digestion, reduces psychological distress and induces relaxation<sup>29,30,42-44</sup>.

Exercising frequently creates the conditions for delaying the onset of episodes of falls, alleviates fear due to a possible fall and generally induces a desirable attitude regarding the quality of life of the person. Existing studies are insufficient in terms of highlighting specific aspects of mobility control<sup>13,42</sup>.

Hypothetically, Tai Chi exercising may train people of advanced age in weight shifting or torso rotation, while improvement in gait is expected during periods when body mass shifting has occurred<sup>13,30</sup>. Proof exists that people in later life may become satisfactorily stronger, improve their balance and have a positive effect on their walking speed<sup>29,42</sup>.

Tai Chi seems that through different mechanisms balances and facilitates the concentration of the body's position of a direct environment<sup>29</sup>. Tai Chi implements holistic approach to developing flexibility, vigor and cardiological benefits. After 12 weeks, reduced grip strength, reduced rotational speed, reduced systolic pressure, and reduced frequency of falls were recorded<sup>29</sup>.

Performing Tai Chi requires a low centre of gravity, with the knees and hips held in flexion, so that any benefits after resistance exercise are retained. Wolf et al. report sustained improvement in balance and strength, six months after a Tai Chi training program<sup>29</sup>. Hain et al. revealed that after 8<sup>th</sup> week of Tai Chi practice and training, notable benefits were recorded<sup>30</sup>.

Owings et al. formulated intervention exercises, including reduced-intensity and flexibility resistance movements, resistance with balance exercises on a special equilibrium platform, Tai Chi balance practice along with taking part in functional actions. Findings demonstrated considerable lowering in the risk of falls, in contrast to other types of exercises that further increased this risk<sup>45</sup>.

In 1996 Wolf et al. reported that Tai Chi exercises were unrelated to orthostatic control, although participants had reduced falls and lowered fear of falling, compared to the control grouping<sup>29</sup>. Crilly et al. reported no remarkable reduction in static postural sway, recorded after 12 weeks of a program of balance and endurance exercising<sup>30</sup>. Liechtenstein et al. noted as well the lack of consequences regarding orthostatic control in a similar type of program<sup>30</sup>. A 10-week exercise program had a positive impact on 10 participants who had chosen a sedentary lifestyle and were confined to a hospital facility by increasing the total duration balance of the one leg standing. Within the same year Hopkins et al. reported that reduced-intensity aerobic dance in older women significantly improved the duration of standing on one leg<sup>30</sup>.

## Conclusions

Maintaining balance and postural control is of utmost importance for the older adults. Calculation of proprioception using subjective criteria and functional evaluation is central to identify related problems. Interventions to improve proprioception include balance training, empowerment and strength exercising, combined equilibrium and strength exercising, general training and Tai Chi.

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