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Active ocular vergence improves postural control in elderly as close viewing distance with or without a single cognitive task

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HIGHLIGHTS

- Effects of vision, eye movement, viewing distance and cognitive task were studied on postural control in autonomous elderly individuals.
- We measured body oscillations with accelerometers placed at the lumbosacral level, near the center of mass.
- The postural stability decreased when fixating on LED at 150 cm vs. 20 cm distance with or without simple cognitive tasks.
- Active vergence between the LEDs improved the postural stability while eye closure decreased it.
- In elderly, we found a beneficial contribution of vergence eye movements for a better postural control.

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ABSTRACT

Performance of the vestibular, visual, and somatosensory systems decreases with age, reducing the capacity of postural control, and increasing the risk of falling. The purpose of this study is to measure the effects of vision, active vergence eye movements, viewing distance/vergence angle and a simple cognitive task on postural control during an upright stance, in completely autonomous elderly individuals. Participated in the study, 23 elderly subjects (73.4 ± 6.8 years) who were enrolled in a center dedicated to the prevention of falling. Their body oscillations were measured with the DynaPort® device, with three accelerometers, placed at the lumbosacral level, near the center of mass. The conditions were the following: eyes open fixating on LED at 20 cm or 150 cm (vergence angle 17.0° and 2.3° respectively) with or without additional cognitive tasks (counting down from one hundred), performing active vergence by alternating the fixation between the far and the near LED (convergence and divergence), eyes closed after having fixated the far LED. The results showed that the postural stability significantly decreased when fixating on the LED at a far distance (weak convergence angle) with or without cognitive tasks; active convergence-divergence between the LEDs improved the postural stability while eye closure decreased it. The privilege of proximity (with increased convergence at near), previously established with foot posturography, is shown here to be valid for accelerometry with the center of mass in elderly. Another major result is the beneficial contribution of active vergence eye movements to better postural stability. The results bring new perspectives for the role of eye movement training to preserve postural control and autonomy in elderly.

1. Introduction

Postural control requires the integration of visual, vestibular and somaesthetic inputs by the central nervous system which produces their appropriate and coordinated transformations, and generates adapted muscular response as corrective torque through the action of a feedback control system (e.g. See [33]). Maintaining postural stability is an active complex process. However, postural control performance in ageing individuals is known to decrease. Indeed, physiologically, there is impairment in visual, vestibular, and somaesthetic captors; the speed of nervous system's information changes in the mode of information processing in the brain and last muscle effectors (see [28]). This physiological degradation could lead to various difficulties/pathologies such as loss of autonomy, falls, or the fear of falling; the prevalence and severity of posture and gait disorders increases with aging [29]. Postural

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impairment is amplified when cognitive tasks are performed (e.g. [5,15,22]) and these impacts on motor efficiency are more affected in fallers or in the case of fear of falling (e.g. [30,31,45]). Falls are a real public health concern, with financial cost (e.g. [43,44]).

If vestibular and somaesthetic systems are impaired with ageing (e.g. [13,26]), vision will be also impaired (e.g. [27,37]) and some studies also suggest eye movement deterioration namely, for smooth pursuit, saccades and vergence duration (e.g. [52,54]). Recent studies have shown that eye movements such as vergence impact postural stability. For instance stability is better when the eyes are converging at near target distance than at far (e.g. [19,24]); these results were found in young adults and in seniors (mean age 62 years, range 55–71). Other studies in dyslexic children [17] and in adults suffering from vestibular pathology (mean age 52 years, range 26–77) or in healthy adults (mean age 32 years, 22–59 range) [18] have both shown an improvement of postural stability when subjects actively perform vergence (back and forth eye movements between a far and near target). Therefore, based on these positive effects of active vergence on posture, a question of interest is whether the postural control in terms of stability *per se* is improved by vergence in elderly. During aging, there is an interest in stimulating the motor functions for a beneficial effect on sensorimotor integration, cognitive processes, emotional and social life, and such physical exercises as balance or aerobic fitness training (e.g. [21,29,48]). In this context, various structures exist as found in Paris (France), the ADAL (A la Découverte de l'Age Libre—[To the discovery of the free age]) to maintain and update the health capital to develop independence for years to come. Thus, the aim of the present prospective study is to test postural control in aged subjects preserving their autonomy and attending this location for physical exercises. The study uses accelerometers near the body center of mass and tests postural control with eyes fixating a near or a far target (i.e. with an increased or decreased eye convergence angle, respectively), or while making active vergence eye movements between both targets. Moreover, each of these conditions was run with and without a simple cognitive task (counting down by steps of two). We expected to show that active vergence would improve postural control in such subjects as well.

2. Materials and methods

2.1. Ethics statement

The postural control investigation complied with the tenets of the Declaration of Helsinki and was approved by the local human experimentation committee, the "Comité de Protection des Personnes" (CPP) Ile de France VI (No: 7,035), Necker Hospital in Paris, France. Written, informed consent was obtained from the participants after the nature of the procedure had been explained.

2.2. Subjects

Twenty-three elderly subjects (21 females, 2 males) were recruited in arrival order in a center dedicated to falling prevention, the ADAL structure in Paris, in the age range of 61–85 years-old (73.4 ± 6.8). Their motivation was to maintain a good form and equilibrium via the exercises proposed in this center. Some of them had a falling history (with no traumatism), others did not have falling history but were generally concerned by falling due to their age; the fear was not measured, just expressed in the interview before our recordings. Patients were responding to prevention actions organized by ADAL. So, it was recruitment where people were autonomous/independent with no history of surgery within the last six months. We recorded their detailed medical histories (see Table 1), including number of and types of drugs consumed per day, the number of falls, if any, during the last year, if they practiced any physical activities and if so, which ones. We also assessed cognitive function using the mini-mental state examination (MMSE) [9] and the level of dependence using the activities of daily living (ADL) [20]. Various visual and oculomotor tests were also done. All subjects wore their habitual glasses adapted to their vision.

Table 1
Characteristics, clinical and antropometric data of elderly participants ($n = 23$).

MMSE (/30)	28.3 ± 1.6	
ADL (/6)	5.9 ± 0.1	
Parinaud	2.1 ± 0.5	
PPC (cm)	9.3 ± 4.3	
Stereo Test (sec. d'arc)	80.8 ± 44.2	
Glasses	23/23	
Visual defect	19/23	Myopia, astigmatism, hypermetropia, presbyopiaas Glaucoma, cataract
Medication	19/23	
Back pain	15/22	
Physical activities	23/23	
Fallers	16/23	
Fear of falling	7/23	

3. Methods

The postural stability in upright stance was evaluated through the body sway measured with the little DynaPort MiniMod® (McRoberts B.V. The Hague, The Netherlands) device (74 g) equipped with three orthogonally mounted accelerometers in transverse, sagittal and coronal planes (AXXL202, Analogue Devices, Norwood MA, USA), placed at the lumbosacral level on a belt and near the body's center of mass. The sampling frequency is set to 100 Hz. This device is known to be easily used in elderly (e.g. [12]), during various activities such as cycling, sitting, standing (e.g. [39], in elderly [7], and recently during only quiet upright stance [18].

3.1. Postural parameters

We measured the following parameters: (1) the normalized area (in mm^2/s), area of an ellipse that contains 95% of the data points, divided by the duration of the measurement, (2) the Root-Mean-Square of Medio-Lateral body sway (RMS of M/L in mm), (3) the Root-Mean-Square of Antero–Posterior body sway (RMS of A/P in mm), (4) the RMS of M/L velocity (in mm/s), (5) the RMS of A/P velocity. These parameters are extracted from the raw gravitational acceleration data in g. After the data are high-pass filtered, velocity is calculated in the A/P and M/L direction by integration of the acceleration signal, and displacement by integration of the velocity signal (for more details see [32,51]).

3.2. Testing conditions

For each participant, postural stability was recorded in upright stance and barefoot, the feet placed side-by-side forming a 30° angle and with the heels separated by 4 cm. Participants were in front of a horizontal table with LED placed at 20 and 150 cm at eye level in a lighted room (see Fig. 1a). The two LEDs were aligned in the median plane and could either be turned on or not. The required mean vergence angle (inverse tangent of the ratio of inter pupil distance divided by viewing distance) for fixating the LED at 20 cm is about 17.0° and 2.3° for fixating at 150 cm (e.g. see [17,25]). The following counterbalanced conditions were run: eyes open fixating