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Evaluation of postural balance in mild cognitive impairment through a three-dimensional electromagnetic system^{☆,☆☆}



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KEYWORDS

Elderly;
Mild cognitive
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Sensory deprivation

Abstract

Introduction: Elderly people with cognitive impairment are at greater risk for falls; thus, an understanding of the earliest stages of cognitive decline is necessary.

Objective: To compare postural balance between elderly people with and without mild cognitive impairment using a three-dimensional system.

Methods: Thirty elderly people with mild cognitive impairment and thirty healthy elderly subjects were selected. Static posturography was performed using three-dimensional electromagnetic equipment and the following parameters were evaluated: maximum displacement, mean speed and total trajectory. Open- and closed-eye stabilometric variable comparisons between groups and within each group were carried out, and a relationship between the Mini Mental State Examination and the total trajectory of all elderly subjects was determined.

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PALAVRAS-CHAVE

Idoso;
Comprometimento
cognitivo leve;
Equilíbrio postural;
Privação sensorial

Results: The analysis among open- and closed-eye conditions showed a significant difference in maximum anteroposterior displacement in the control group and a significant difference in all stabilometric variables in the mild cognitive impairment group. A significant difference between the groups in all variables in the closed-eye condition was observed. There was a strong correlation between cognitive performance and total trajectory.

Conclusion: Evaluations showed decrease in balance in elderly people with mild cognitive impairment. Presence of anteroposterior displacement can be an early sign of postural control impairment, and the evaluation with visual restriction can be useful in detecting small postural instabilities.

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Avaliação do equilíbrio corporal no comprometimento cognitivo leve através de sistema eletromagnético tridimensional

Resumo

Introdução: Idosos com alteração cognitiva apresentam maior risco de quedas; assim, é importante compreender as primeiras fases do declínio cognitivo.

Objetivo: Comparar o equilíbrio corporal entre idosos com e sem comprometimento cognitivo leve através de um sistema tridimensional.

Método: Trinta idosos com comprometimento cognitivo leve e 30 idosos saudáveis foram selecionados. A posturografia estática foi realizada utilizando equipamento eletromagnético tridimensional, e foram avaliados os parâmetros deslocamento máximo, velocidade média e trajetória total. Foi realizada comparação das variáveis estabilométricas com olho aberto e olho fechado intragrupo e intergrupos, e foi estabelecida a relação entre o Mini Exame do Estado Mental e a trajetória total de todos os idosos.

Resultados: A análise entre olho aberto e olho fechado no grupo de controle evidenciou uma diferença significativa no deslocamento anteroposterior máximo; no grupo com comprometimento cognitivo leve, houve diferença significativa em todas as variáveis estabilométricas. Foi observada diferença significativa entre os grupos em todas as variáveis na condição de olho fechado. Houve forte correlação entre desempenho cognitivo e trajetória total.

Conclusão: As avaliações evidenciaram diminuição do equilíbrio nos idosos com comprometimento cognitivo leve. O deslocamento anteroposterior pode ser um sinal precoce de comprometimento do controle postural, e a avaliação com restrição visual pode ser útil na detecção de pequenas instabilidades posturais.

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Introduction

The presence of cognitive impairment is a major risk factor for changes in motor performance and body balance.¹⁻⁴ Studies show that the incidence of falls in people with cognitive impairment is estimated to be twice the incidence in cognitively intact elderly people.⁵ A good approach to reduce the risk of falls in this population is to gain an understanding of the early stages of cognitive decline.

Mild cognitive impairment (MCI) is a clinical condition defined by clinical, cognitive and functional criteria. In this entity, there occurs a greater cognitive decline than that expected for an individual's age and level of education, but that decline does not interfere significantly with daily functional activities.⁶

Elderly people with MCI are at increased risk not only for conversion to dementia, but also for a decline in mobility and for suffering falls. Boyle et al.⁷ suggested that these motor changes may precede the diagnosis of cognitive decline. Although the mechanism that leads to an increased risk of falls in people suffering cognitive impairment is not yet completely understood, it is known that deficiencies in cognitive skills can reduce attention paid to postural skills. Thus, MCI is an opportunity to intervene in the trajectory of cognitive and functional decline in the elderly.⁸

Instrumental techniques have been used to assess balance, in addition to assessments based on clinical judgment, among them, the computed posturography.⁹ However, a major difficulty for its use is the cost of equipment (force platform) and restrictions to its transportation.

Among the latest technologies used in studies of body sway, the three-dimensional system of electromagnetic sensors detects small body movements, allowing a direct investigation of motion kinematics, and has a lower cost and greater portability than the force platform.^{10–17}

During the aging process, a number of changes occur in motor, sensory and cognitive systems, that result in an increase of body sway.^{1,2} One way to assess the contribution of sensory systems in postural control is by manipulating this information during stance.¹⁸

In this sense, the body sway evaluation in different sensory conditions can be useful in detecting imbalance in elderly patients with MCI. The aim of this study was to compare the static body balance in elderly populations with and without MCI, using data from a three-dimensional system, under open- and closed-eye conditions.

Methods

Participants

This is a cross-sectional, descriptive and comparative study. Two groups of 30 elderly subjects were defined: control group (elderly people without cognitive impairment) and a group with MCI.

The sample calculation was carried out based on a survey of the number of consultations and on previous studies conducted in the outpatient clinic, as well as in estimates based on the literature, through the statistical program G*Power 3.1[®]; an indicative sample of at least 27 subjects for each group was obtained.

Participants in the MCI group were selected subsequent to multidisciplinary assessment at our outpatient clinic, and the control group participants were selected from other clinical departments from the hospital.

To define the diagnostic groups, the MCI group was composed of elderly subjects with a clinical diagnosis according to criteria developed by Petersen et al.¹⁹ These patients should show some cognitive impairment, with predominance of mnemonic function (amnesic-type MCI), but without compromising their functional capacity. MCI patients also should show absence of dementia by the International Classification of Diseases 10th edition (ICD-10) criteria, by the Diagnostic and Statistical Manual of Mental Disorders 4th edition (DSM-IV), through changes in the battery of neuropsychological tests, and by a Clinical Dementia Rating (CDR)=0.5. The control group should not exhibit evidence of cognitive or functional impairment, according to their clinical and neuropsychological evaluation.²⁰

Individuals of both genders, aged 65–75 years, matched for age, and with a minimum of four years of formal education were included in our two groups. Elderly subjects using metal devices or a pacemaker inside the body, exhibiting memory changes secondary to other degenerative diseases, with severe cardiovascular disorder, a non-corrected visual or hearing impairment, prior musculoskeletal and neurological changes that would influence the subject's balance, vestibular disorders, complaints of dizziness and/or vertigo, or the use of psychotropic drugs were excluded from this study. In addition, individuals with a significant decrease in daily activities, history of falls (defined as an unexpected

event in which the subject will be positioned on the ground or on a lower level than his/her own level),²¹ and ambulatory device users were also excluded from this study.

After the approval of this research by the Institutional Ethics Committee (number 5,156/2010), all subjects were informed about the evaluations and signed a free and informed consent form.

Procedures and instruments

At first, we collected personal and anthropometric information, as well as information on general state of health and cognitive performance by applying the Mini Mental State Examination (MMSE). An assessment of physical and functional performance was carried out, in order to become aware of the functional aspects of the elderly and to exclude the possibility that potential sensory and motor deficits would compromise the static body balance test. With this in mind, the participants were submitted to the Freiburg test of visual acuity (modified version),²² the Dix-Hallpike maneuver²³ and the Short Physical Performance Battery (SPPB),²⁴ and a tuning fork was bilaterally applied to the mastoid process.

The static body balance was evaluated using the Polhemus® Patriot three-dimensional electromagnetic sensor system (Fig. 1). The position and spatial orientation of the elderly were recorded in real time by plotting their movements in the anteroposterior, mediolateral and vertical axes (positions x , y , z and orientation angles θ , φ , ρ) between the receiver sensor attached on the subject's skin on the sacral region (near the center of mass), and the transmitter sensor, which was placed on a support uncoupled from the participant's body, at a distance of approximately 40 cm and at the same height as the receiver sensor.^{10–14} The data acquired by the system were transferred to a notebook via an USB interface and with a LabView 8.0 environment through a specific software. Sampling acquisition frequency was of 100 Hz.

In order to establish a signal pattern and obtain reliable data, the baseline shift of the Polhemus equipment

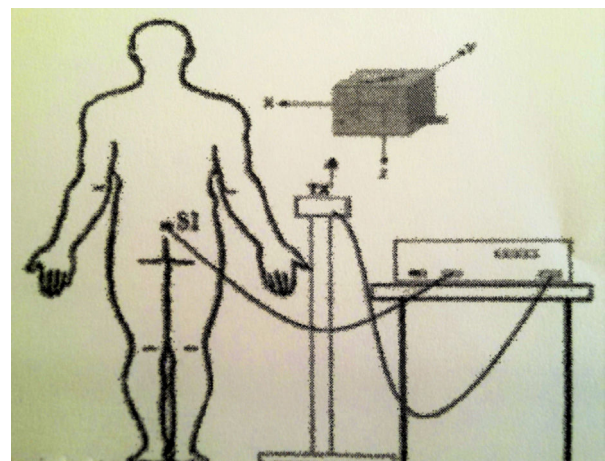


Figure 1 Location of electromagnetic sensors. Tx, transmitter and three-plane representation. S1, sacral region. Adapted from Carneiro et al.¹⁰

Table 1 Demographic and anthropometric characteristics, MMSE scores, and physical and functional characterization in diagnostic groups.

	Control	MCI	p-Value
Gender ^a (M:F)	12 (20%): 18 (30%)	10 (17%): 20 (33%)	0.789
Age ^b (years)	70.7 ± 2.76	69.3 ± 2.95	0.062
Weight ^b (kg)	71 ± 12.16	66.5 ± 9.47	0.113
Height ^b (cm)	165 ± 8.09	166 ± 6.48	0.972
Education (years)	7.2 ± 1.61	6.97 ± 1.90	0.610
MEEM ^b (score)	27.03 ± 1.63	24.6 ± 2.46	<0.001
Visual acuity ^b	1.5 ± 0.72	1.6 ± 0.87	0.672
SPPB ^b	9.86 ± 0.97	8.76 ± 0.93	<0.001

MCI, mild cognitive impairment; MMSE, Mini Mental State Examination; SPPB, Short Physical Performance Battery.

^a Cardinal numbers and percentages.

^b Mean ± standard deviation.

was verified and the equipment was calibrated prior to the evaluation by moving the coil of the sensor 5 cm forward on a flat surface. Considering that the three-dimensional system works as a motion sensor, it should detect the same previously known displacement.

During body sway assessment, the participants remained in an orthostatic position, with bipedal support and with their arms placed alongside the body, with bare feet in a side-by-side position and parallel to the width of the pelvis, on a wooden platform measuring 1 cm × 50 cm × 50 cm and keeping a distance of about 12 cm between their heels during the evaluation.²⁵ Additionally, all participants were instructed to stand still as much as they could and not move their arms. During the test, no communication was allowed.

The test was conducted in two sensory conditions for 60 s for each position in the following order: open eyes (OE) and closed eyes (CE) condition. In OE condition, all participants were instructed to maintain their eyes fixed at a point placed at eye level and at a distance of one meter.

The body sway parameters (stabilometric variables) analyzed were: maximum anteroposterior (AP) and mediolateral (ML) displacement, total trajectory, and total average speed.^{10–17} A variable/height calculation was performed for statistical analysis, with data correction for height of the elderly subjects.

Statistical analysis

To check sample homogeneity, we applied the Kolmogorov–Smirnov test. The comparisons of anthropometric, demographic, educational, and physical and functional variables and MMSE scores between control and MCI groups were carried out using the Student's *t* test. The gender ratio in each group was verified by the Fischer Test. To compare stabilometric variables for OE and CE conditions within each group, the Wilcoxon test was used, and for the comparison between groups, the Mann–Whitney test was applied. Spearman coefficient was used to test the correlation between the variables with and without adjustment for the height of participants and between MMSE scores and total trajectory in those two sensory conditions. Statistical analyses were conducted using SPSS software (SPSS for Windows, version 16.0, SPSS Inc., USA), considering a 5% significance level. For preparation of

charts we used the statistical package Origin®, version 6.0 (Mi-crocal Origin®, 6.0, USA).

Results

In [Table 1](#), one can see that there was no significant difference between the diagnostic groups regarding gender, age, weight, height, and education; on the other hand, there was a significant difference in MMSE scores, and it can also be observed that the elderly from the control group showed better cognitive performance. All elderly subjects had their proprioceptive sensitivity preserved, a negative response to Dix–Hallpike maneuver, preserved visual acuity preserved and they managed to realize the SPPB test.

[Table 2](#) shows variables of body sway in groups in OE and CE conditions, and the comparisons between intra- and intergroups' sensory conditions. The analysis between OE and CE in the control group only showed a significant difference in maximum AP displacement ($p < 0.01$), while in the MCI group a significant difference among all stabilometric variables was detected ($p < 0.001$).

When the comparison between groups was analyzed, there was no significant difference between the variables ($p > 0.05$) in OE condition. In CE condition, we observed significant differences between groups for all variables ($p < 0.01$). In this study, variables corrected for height are not presented, because of their strong correlation (r : 0.91; $p < 0.001$) with uncorrected variables.

[Fig. 2](#) shows statokinesiogram graphs, representing the total 60-s trajectory of body sway in AP *versus* the ML axis for a healthy subject *versus* an elderly MCI of the same gender and with homogeneity of anthropometric values in different sensory conditions. By analyzing these charts one can see that the less sensory information the elderly has, the greater the body oscillation.

[Fig. 3](#) shows the stabilogram of the same elderly subjects in different sensory conditions. The graph shows the ranges of body sway in relation to the acquisition time in AP and ML axes. Stabilograms allow the identification of those test periods in which the individual has obtained greater oscillation peaks (higher risk of falls).

Considering all of the participants (not separated by groups), the correlation analysis between the MMSE scores and overall trajectory of sensory conditions OE and CE led

Table 2 Parameters of body sway of the two study groups in different sensory conditions.

Postural sway			
	OE	CE	<i>p</i> -Value ^a
<i>Max AP displ (cm)</i>			
Control	1.45 ± 0.42	1.92 ± 0.81	<0.01
MCI	1.61 ± 0.40	6.04 ± 1.89	<0.001
<i>p</i> -Value ^b	0.062	<0.001	
<i>Max ML displ (cm)</i>			
Control	0.93 ± 0.43	1.25 ± 1.11	0.070
MCI	1.08 ± 0.28	4.36 ± 2.24	<0.001
<i>p</i> -Value ^b	0.084	<0.001	
<i>Total trajectory (cm)</i>			
Control	65.04 ± 31.98	68.14 ± 29.17	0.199
MCI	65.53 ± 40.57	117.17 ± 35.43	<0.001
<i>p</i> -Value ^b	0.517	<0.001	
<i>Tot av speed (cm/s)</i>			
Control	1.07 ± 0.56	1.15 ± 0.49	0.264
MCI	1.09 ± 0.38	1.97 ± 0.60	<0.01
<i>p</i> -Value ^b	0.451	<0.01	

MCI, mild cognitive impairment; Max AP displ, maximum antero-posterior displacement; Max ML displ, maximum mediolateral displacement; Tot av speed, total average speed; OE, open eyes; CE, closed eyes.

^a *p*-Values in the column according to paired Wilcoxon test.

^b *p*-Values in lines according to Mann-Whitney test.

to the finding of a significant correlation (OE: $r = -0.65$; $p < 0.01$ and CE: $r = -0.92$; $p < 0.01$); and, as the MMSE value increased, the value of the total trajectory diminished for the entire sample.

Discussion

Although much research has been devoted to the study of falls in elderly patients with dementia (mostly with

Alzheimer's Disease), few studies have addressed elderly people with MCI. Consequently, the incidence of falls in this population and their risk factors remain poorly defined. In this study, the static postural control of subjects in a standing position and its changes in the presence of MCI were examined. Traditionally, the standing position has been quantified using characteristics of body sway and changes in the pressure center. Recently, however, new technological devices for this evaluation have been evaluated. To the extent of our knowledge, this was the first study to analyze static body balance in elderly people with MCI using a three-dimensional system in sensory conditions OE and CE, and the analysis of our findings revealed poorer body balance in that group, in agreement with other posturographic studies conducted in this population.^{26,27}

For the conduction of this study, 60 elderly subjects were selected. The proportions of men and women were similar in both groups; thus, the differences that could be observed between groups would not be attributed to differences in gender distribution. Other studies utilized a similar design.^{3,4,26} The age distribution was homogeneous in our groups; thus, the effect of this variable in the results was controlled, since age is a known risk factor for falls. Also, significant differences between the groups regarding anthropometric variables were not observed.

The analysis of static body balance in different visual conditions enabled an analysis of the impact of vision to maintain the balance in both groups studied. We could observe that there was no significant difference in stabilometric variables between controls *versus* the MCI group in terms of OE condition, in which all elderly subjects have used the three sensory systems to maintain balance. However, in CE condition, a significant difference between these groups in all stabilometric variables was observed, and the MCI group showed increased body sway compared to the control group, indicating that the MCI group needed more visual information to maintain balance.

Studies using posturography in elderly patients with MCI are still limited. Shin et al.,³ Leandri et al.²⁶ and Merlo et al.²⁷ conducted similar research. The study by Leandri et al.²⁶ drew attention to differences between MCI and

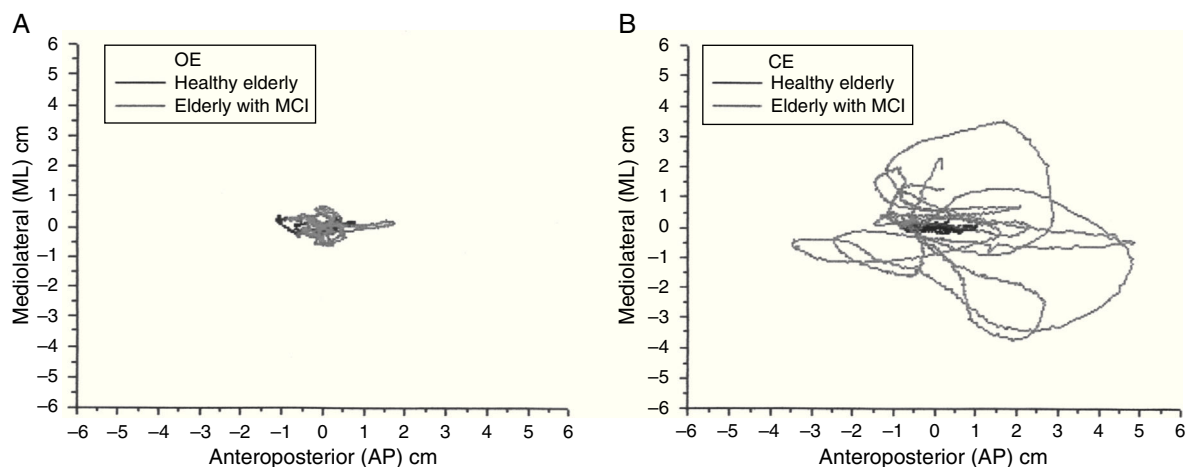


Figure 2 Statokinesiogram from a healthy elderly and of another with mild cognitive impairment (MCI). A, open (OE) and B, closed (CE) eyes in anteroposterior (AP) and mediolateral (ML) direction.

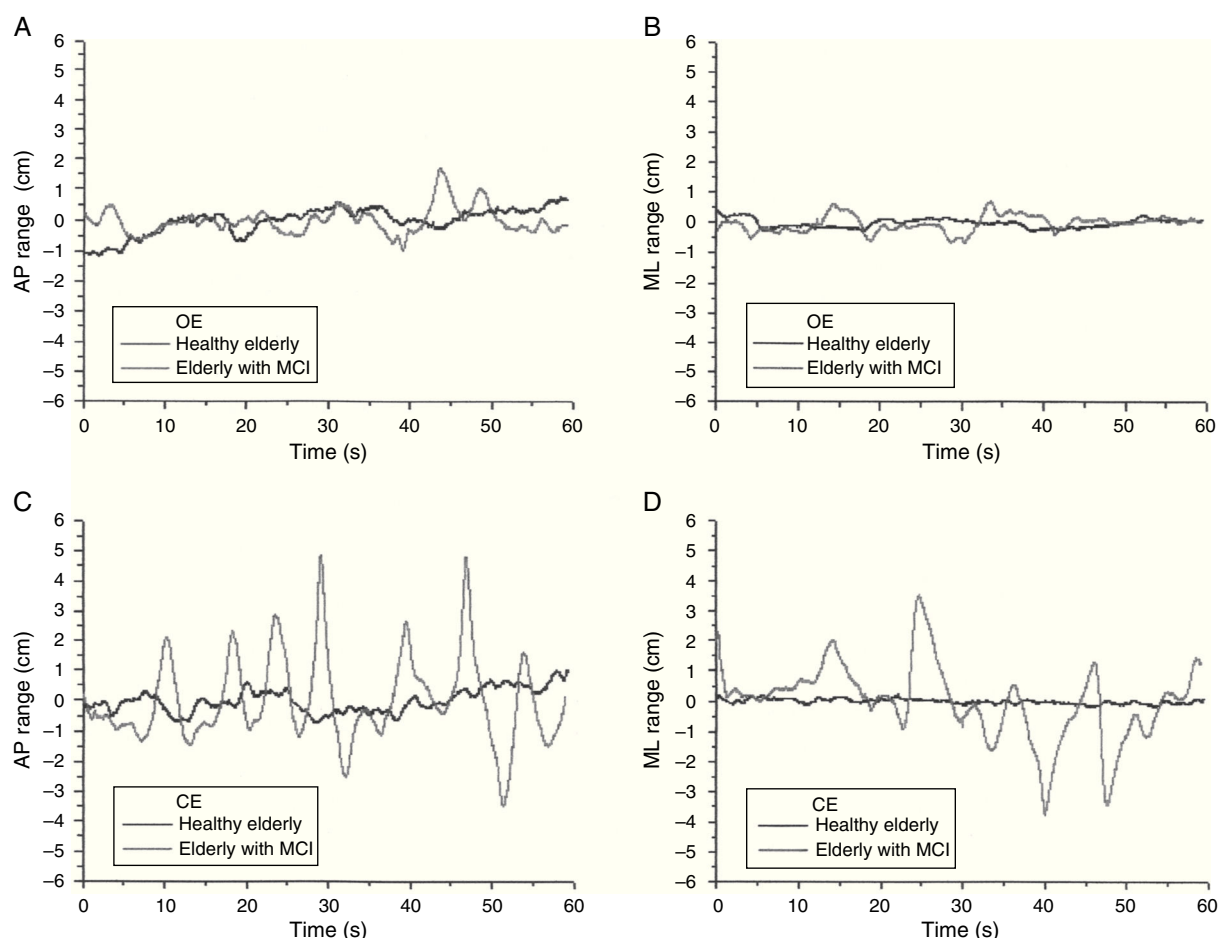


Figure 3 Stabilogram from a healthy elderly and from one with mild cognitive impairment (MCI). Open eyes (OE) in an anteroposterior (AP) direction. B, open eyes (OE) in a mediolateral (ML) direction. C, eyes closed (EC) in an anteroposterior (AP) direction. D, eyes closed (EC) in a mediolateral (ML) direction.

Alzheimer's disease (AD) groups. These researchers found significant differences in AP displacement between control and MCI groups, and subsequently between MCI and AD groups. There was no significant difference in the variable "ML displacement" between MCI and control groups, but this difference occurred between MCI and AD groups. Thus, AP displacement showed a steady increase among the three groups assessed, showing that early changes in the balance of elderly people may occur, in parallel with motor changes already observed in clinical trials.²⁸⁻³⁰

Taylor et al.³¹ showed that older women with MCI had more risk factors for falls than healthy elderly women, as well as greater changes in clinical trials and an increase in body sway, especially with CE, which corroborated studies conducted by Franssen et al.,²⁹ Boyle et al.³², and Liu-Ambrose et al.³³ The greater body sway in CE condition in the MCI group compared with the control group, as observed in these studies, confirms the importance of vision in maintaining body stability. In our study, the absence of a visual cue resulted in higher body sway in the MCI group, replicating the findings from the studies cited above. These results also indicate that an overload may occur in other sensory

(vestibular and somatosensory) systems, in order to maintain balance and prevent falls.

After testing the multisensory integration ability of elderly people with MCI and AD, Wu et al.³⁴ observed that the reaction time not only of elderly people with AD, but also of those with MCI, was slower than in healthy individuals. This finding suggests that cognitive deficits found in elderly people with MCI may already lead to a lower multisensory integration, which reduces their functional performance compared to healthy elderly subjects.

When comparing the same groups with OE and CE, subjects belonging to the control group only showed a significant difference in maximum AP displacement, while the MCI group showed significant differences for all stabilometric variables assessed.

The importance of the visual system to postural control is mainly related to the stabilization of body sway. Of these oscillating parameters, AP displacement is most often related to the stability of the body, since this movement is implemented by the action of the ankle and, later of the hip. It seems that visual control is an important factor in postural control during dynamic activities. In the static

posture, studies have shown no differences in body sway among healthy elderly people in the absence of vision, except in AP displacement.^{26,35–37}

Sarabon et al.³⁵ and Fujita et al.³⁷ showed improvement in postural control efficiency according to age in healthy individuals, but observed no differences in body sway with OE and CE between groups of different ages. These results contradict studies that highlight a high reliance on visual information in the elderly population.³⁸

On the other hand, in older adults with MCI visual information seems to play a greater role in controlling body balance, since the sensory compensation does not occur so efficiently, due to the lower sensory integration demonstrated by such patients.³⁴ As these elderly people present with a lower somatosensory input in their lower limbs, as well as a possible change in vestibular system, their visual system gets overloaded, and visual deprivation triggers a greater change of static equilibrium. This result was confirmed by Shin et al.³ and Leandri et al.²⁶ in studies involving elderly people (with MCI *versus* healthy subjects), demonstrating that visual deprivation was significantly associated with a greater body displacement seen in the MCI group, mainly in AP direction.

Another hypothesis that may explain the greater need of visual information in the MCI group is the relationship between this sensory information and cognition. It is known that the visual afferents are an important source of information for the formation of postural orientation. The reduction of such information would lead to a greater need of cognitive involvement in sensorimotor processing.³⁸

Attentional and executive resources play an important role in the decline of spatial memory, usually associated with the healthy aging process. However, studies point to a greater decrease of this spatial memory in older adults with MCI. In addition, changes in parietal white matter, entorhinal cortex, and posterior cingulate may adversely affect the successful use of attentional resources to postural control in these elderly patients with MCI.³⁹

The relationship between cognitive performance through MMSE and total trajectory in sensory conditions (OE and CE) for all participants was established through a correlation analysis. One can observe a moderate correlation between MMSE and OE, and a strong correlation between MMSE and CE. This finding shows that increases in MMSE score are coincident with decreases in total trajectory value, *i.e.* those elderly participants with a better cognitive performance exhibited less oscillation in the standing posture. This association was also observed in other studies.^{26,40,41} These results indicate that cognitive function is a critical aspect for these elderly people, and compared to traditional tests of cognitive function, motor performance evaluations can be sensitive, to identify people affected in the early stages of cognitive dysfunction.

It should be noted that the decreased balance in elderly people with MCI has a clinical significance beyond the risk of falls. Evidence suggests that this decline is related to an increased risk of AD.²⁸ It may be that people with MCI may have greater physiological impairment compared to individuals not affected by this condition, because of structural and functional brain abnormalities.⁴²

Although clinical assessment scales are used for balance assessment, some of these tests may not be as sensitive to

detect low levels of balance dysfunction such as that found in the early stages of cognitive impairment.²⁹ Newer technologies using magnetic transducers to detect body sway and weight transfer during static or dynamic posture provide more sensitive measurements to evaluate small changes in balance.⁹

In this regard, several studies have assessed body balance using the three-dimensional system of electromagnetic sensors.^{10–17} The use of this tool in our study proved useful in defining the rehabilitation goals and obtaining important information about the monitoring of therapeutic results. Some of its biggest advantages are that the system can be transported to different locations, has a low implementation cost, and also provides simple data for its analysis and interpretation.

The clinical implication of this study is that the risk assessment of falls should be a key component in the clinical management of elderly patients with MCI. Specifically, studies suggest the inclusion of body sway measures for this population.³³ It may be that changes in stabilometric parameters, particularly in AP direction, may be an early sign of impaired postural control, and evaluations in an CE environment may be useful to better differentiate between those small postural instabilities associated with aging and pathological processes that affect postural control. Early detection of abnormalities in postural control, followed by an appropriate rehabilitation, environmental changes, and appropriate recommendations, can help prevent falls and improve the quality of life of the elderly.

Conclusion

The assessments showed a decrease of body balance in elderly subjects with MCI. In addition, AP displacement may be an early sign of postural control impairment, and a vision-restricted evaluation may be useful in detecting cases of small postural instability.

Conflict of interests

The authors declare no conflicts of interest.

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