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Improvement of visuospatial function in older people undergoing vestibular rehabilitation

Aprimoramento da função visuoespacial em idosos submetidos à reabilitação vestibular

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ABSTRACT

Purpose: To verify whether visuospatial function improves in older adults with vestibular dysfunction undergoing vestibular rehabilitation. **Methods:** Longitudinal, analytical, quasi-experimental study (interrupted time series) with a sample of 52 older adults of both sexes, aged 60 to 86 years. The study included individuals with vestibular dysfunction confirmed by the vestibular evoked myogenic potential and Video Head Impulse Test. Visuospatial function was assessed before and after eight vestibular rehabilitation sessions using the simplified Taylor Complex Figure. The Wilcoxon test compared the variables before and after the vestibular rehabilitation. The Reliable Change Index was used for intra-subject analysis before and after the intervention. The significance level was set at 5% ($p < 0.05$). **Results:** Participants' response (values) in the assessment were below that which would be expected for their age and education level in the three categories: copy (17.14), immediate recall (7.43), and delayed recall (4.54). Visuospatial function improved after the intervention, mainly in the immediate recall (7.0/9.75) and delayed recall (2.5/8.5). **Conclusion:** The older people performed better in visuospatial function after vestibular rehabilitation.

Keywords: Cognition; Vestibular system; Dizziness; Rehabilitation; Health of the elderly

RESUMO

Objetivo: Verificar se idosos com disfunção vestibular submetidos à reabilitação vestibular podem apresentar melhora da função visuoespacial. **Métodos:** Estudo longitudinal, analítico e quase experimental (série de tempo interrompida). A amostra foi composta por 52 idosos, de ambos os sexos, com idade entre 60 e 86 anos. Foram incluídos idosos com disfunção vestibular confirmada pelos testes Potencial Miogênico Evocado Vestibular e Video Head impulse Test. A função visuoespacial foi avaliada antes e após oito sessões de reabilitação vestibular, por meio da Figura Complexa de Taylor (simplificada). As variáveis foram comparadas pré e pós-reabilitação vestibular por meio do teste de Wilcoxon. Contudo, para a análise intrassujeitos pré e pós-intervenção, utilizou-se o Índice de Mudança Confiável. Adotou-se o nível de significância de 5% ($p < 0,05$). **Resultados:** Na avaliação, os participantes apresentaram respostas (valores) abaixo do esperado para a idade e escolaridade nas três categorias: cópia (17,14), evocação imediata (7,43) e evocação tardia (4,54). Após a intervenção, verificou-se melhora da função visuoespacial, principalmente nas tarefas de evocação imediata (7,0/9,75) e evocação tardia (2,5/8,5). **Conclusão:** Após a reabilitação vestibular, os idosos apresentaram melhor desempenho da função visuoespacial.

Palavras-chave: Cognição; Sistema vestibular; Tontura; Reabilitação; Saúde do idoso

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INTRODUCTION

The vestibular system participates in the cognitive functions of spatial navigation, spatial perception, body representation, mental imagery, attention, memory, risk perception, and social cognition[1-6]. Visuospatial function is the most studied neurocognitive domain in research on human vestibular dysfunctions[1,3,4,6]. Authors have found a correlation between visuospatial function and a dizziness questionnaire[7,8]. Other studies have observed a relationship between chronic vestibular dysfunction and worse cognitive results in spatial navigation and visuospatial function[7,9,10]. Visuospatial function is closely related to the vestibular system, maintaining body balance through the vestibulo-ocular reflex[1,3,4,6,8,10].

The interaction between the vestibular system and cognition is due to neural connections from the vestibular nucleus to limbic and cortical regions, which are involved in both cognition and spatial orientation[1,3,4,6]. Thus, vestibular dysfunctions may be associated with impaired cognitive abilities[1,3,4,6,8,10].

Vestibular system impairment manifests as dizziness, defined as a mistaken sensation of body or environmental movement[11]. Individuals with dizziness may be at risk of falls, one of the main causes of morbidity and mortality, and the main cause of fatal and non-fatal trauma in older adults[12,13]. The incidence of this symptom increases significantly with age, is associated with depressive symptoms and impaired health self-perception, and restricts participation in social activities[12-15]. Treatment for dizziness is necessary to improve the person's quality of life and functioning[16-19].

Vestibular rehabilitation (VR) is the most widely used treatment for dizziness in clinical practice[16-19]. VR is a speech-language-hearing clinical method that seeks vestibular compensation and habituation through neuronal plasticity, improving spatial orientation and overall balance[16-19]. Among other benefits, it can improve static and dynamic postural control, thus reducing imbalance and increasing self-confidence and quality of life[16-19].

Studies that have evaluated visuospatial function before and after VR are scarce, especially in the Brazilian literature[5,8,10,19,20]. Therefore, this study aimed to verify whether visuospatial function performance improved in older adults with vestibular dysfunction undergoing VR.

METHODS

This is a longitudinal, analytical, quasi-experimental study (interrupted time series), conducted at the Observatory of Functional Speech-Language-Hearing Health of the Medical School of the Federal University of Minas Gerais - OSF/FM/UFMG, between December 2019 and December 2022. Its procedures were approved by UFMG's Research Ethics Committee - CEP/UFMG, under number CAAE 49714221.0.0000.5149.

The sample consisted of 62 older adults aged 60 to 86 years, of both sexes, with vestibular dysfunction proven by vestibular examinations: Video Head Impulse Test (v-HIT)[21] and vestibular evoked myogenic potentials (VEMP)[22]. The sample was selected by convenience, encompassing residents of Belo Horizonte and its metropolitan region who were waiting to begin VR at the speech-language-hearing clinic of UFMG's São Geraldo Hospital – Clinics Hospital. It was not possible to collect control group data or blind the evaluator before and after VR, as one of the researchers assessed, treated, and reassessed the older people. This was necessary to avoid exposing them to a larger number of people, given the restrictions imposed by the COVID-19 pandemic. At the time, there were limitations regarding the number of people frequenting the various locations within the health campus, and older people were considered a risk group.

The participants received explanations about the research objectives and methods; they were also informed that they could withdraw from the research at any time and had access to the results, even if partial. All participants received a copy of an informed consent form and were instructed on how to prepare for the exams, such as not using facial creams or makeup to avoid interfering with the recording of responses, and the importance of not taking labyrinthine medications during VR.

The study included individuals aged 60 years or older, with complaints of dizziness, peripheral vestibular dysfunction (proven by abnormal or absent responses to the cervical and/or ocular VEMP exam and/or semicircular canal gain less than 0.75 on the v-HIT exam), and who voluntarily agreed to participate in the study by signing an informed consent form.

The study excluded individuals with a suspected diagnosis of benign paroxysmal positional vertigo (BPPV), external ear abnormalities on otoscopy, conductive hearing loss confirmed by tympanometry, self-reported difficulty with neck rotation, mental disorder, prior diagnosis of dementia of any etiology, Mini-Mental State Examination (MMSE)[23] score of 18 or less, no impairment on initial objective cognitive assessment, Clinical-Functional Vulnerability Index (CFVI-20)[24] greater than or equal to 15 points, self-reported severe sensory impairment, prior stroke, and those who did not complete the eight VR sessions proposed by the researchers.

Procedures

Participants underwent hearing assessments in an acoustically treated room. Otoscopy was performed using the Mikatos® otoscope, tympanometry with the Otoflex 100 Otometrics® equipment, and audiometry with the Itera II- Otometrics® equipment. Vestibular function was assessed with cervical and ocular VEMP tests[22] and v-HIT[21], with ICS-impulse® equipment from Otometrics®. Firstly, participants answered a questionnaire to collect sociodemographic and otologic history data and verify the possibility of hearing or vestibular alterations.

The study used the simplified version of the Taylor Complex Figure (TCF-S)[25] to assess visuospatial function through copying, immediate recall, and delayed recall. The test consists of a geometric figure printed on a card or A4 sheet; the subject is asked to copy the figure as best as they can (Figure 1). The subject's planning and approach are also assessed as they copy the figure. Three minutes after copying, immediate recall is requested: the participant is asked to draw on paper what they can remember from the drawing. Delayed recall is also requested 20 to 30 minutes after copying. Copying takes less than 5 minutes on average, as does each recall[25]. The normal values, according to the study that validated the Brazilian version, are copy: 20.3, immediate recall: 14.0, and delayed recall: 13.8[25].

All tests were scored considering the participants' age and education level, and all participants were subjected to the same study protocol. Older individuals with impaired visual and

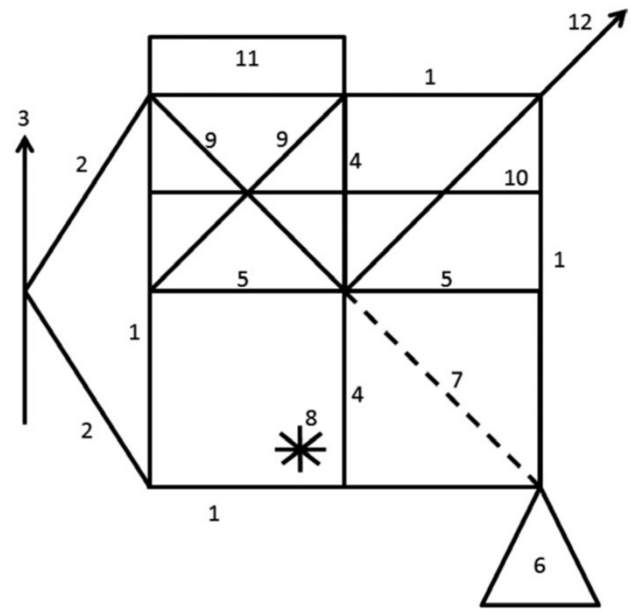

Figure 1. Simplified Taylor Complex Figure
De Paula et al.[25]

auditory acuity used corrective lenses and hearing aids during the cognitive tests.

A VR program of eight individual sessions was applied to treat dizziness, with one 20-minute session per week, according to the individualized method proposed by authors[26,27]. It consists of static, dynamic, and oculomotor balance exercises aimed at compensating for and habituating the vestibular system[19,26,27]. The term "individualized" was used instead of "personalized" because the goal was to use this method to rehabilitate each participant's individual needs[26,27]. The degree of difficulty of the exercises was gradually increased, and participants received instructions to perform the exercises at home, at least once a day, for 20 minutes, receiving control charts to monitor execution at home. Illiterate older adults received images and videos to exemplify the exercises. After VR, participants were reassessed with TCF-S[25].

Five of the 62 older individuals evaluated were excluded because their otoneurologic examinations were normal, five because their MMSE results were below expectations, and five because they did not complete the eight VR sessions proposed by the evaluators, resulting in a final sample of 47 reassessed older people.

Statistical analysis

The collected data were entered into an Excel spreadsheet, paired, and subjected to statistical analysis using the Statistical Package for the Social Sciences (SPSS), version 22.0. The continuous variables were the TCF-S results, which were the study response variables. The categorical variables were the sociodemographic data (age, sex, and education).

A descriptive analysis of the frequency of the categorical variables was initially performed to describe the participants, presented as absolute (n) and relative (%) frequencies. Measures of central tendency (mean and median), dispersion (standard deviation), and position (maximum and minimum) of the continuous variables were also analyzed. The normality of the variables was verified using the Shapiro-Wilk test. The variables did not present a normal distribution and received appropriate statistical treatment, using non-parametric tests.

The participants' vestibular and cognitive variables before and after VR were compared using the Wilcoxon test. The significance level was set at 5% ($p < 0.05$). However, the Reliable Change Index (RCI)[28] was used for the intra-subject analysis of pre- and post-intervention cognitive variables; this statistical procedure compares two scores on psychological tests at two different time points. This method assesses whether the difference in one's score at two time points can be explained by measurement error or represents a truly significant change, with cognitive improvement or worsening. Values equal to or less than -1.96 or equal to or less than 1.96 represent a reliable change at a 95% confidence level (p-value = 0.05).

RESULTS

The participants' ages ranged from 60 to 84 years, with an average of 74 years. Schooling ranged from 0 to 13 years, with an average of 5 years. According to the participants' sociodemographic data, systemic arterial hypertension was prevalent as an underlying disease; dizziness was prevalent after head movement, lasting some seconds; hearing impairment on the left; and tinnitus in more than half of the individuals. The older adults lived with family members, performed activities of daily living (ADLs) independently, and did not use polypharmacy; a few of them had experienced falls.

In the auditory assessment, the participants had mild bilateral sensorineural hearing loss with a speech recognition threshold of 34.36 dB HL on the right and 34.11 dB HL on the left, and a speech recognition index for monosyllabic words of 88.66% on the right and 86.58% on the left. Individuals with hearing loss who were not yet using hearing aids were referred to the referral hearing health service.

Table 1 shows the mean and dispersion data of TCF-S variables. Results below expectations were observed in visuospatial function in all three aspects: copying, immediate recall, and delayed recall.

Participants had reduced gain in the right anterior semicircular canals (0.71) and posterior semicircular canals (right: 0.62; left: 0.67), and a higher percentage of covert corrective saccades in the posterior canals, 14.3% on the left and 36.6% on the right in the v-HIT. Moreover, 31 (60%) individuals showed no response in the cVEMP, and 45 (87%) individuals showed no response in the oVEMP. Participants who responded to the VEMP test obtained latency, amplitude, and asymmetry index values within the normal range for older adults.

Table 2 shows the pre- and post-treatment comparison of the TCF-S. Visuospatial function improved in immediate and delayed recall. RCI analysis (Figure 2) found an improvement in visuospatial function in all three aspects: copying 6 (13%), immediate recall 16 (34%), and delayed recall 18 (38%). Another important detail concerns the worsening of some individuals in the copying 6 (13%) and immediate recall 5 (11%) tasks. These individuals' sociodemographic data were not homogeneous to characterize the group. Most individuals had stable visuospatial function in all three categories: copying 35 (74%), immediate recall 26 (55%), and delayed recall 29 (62%).

Table 1. Descriptive data of the simplified Taylor Complex Figure (n = 52)

Simplified Taylor Complex Figure	Mean (standard deviation)	Minimum	Maximum	Normal values*
Copy	17.14 (4.17)	9	24	20.3
Immediate recall	7.43 (5.46)	0	23	14.0
Delayed recall	4.54 (5.01)	0	18	13.8

*De Paula et al.[25]
Source: Developed by the authors

Table 2. Difference in visuospatial function before and after vestibular rehabilitation (n = 47)

TCF-S	Before VR			After VR			
	Median	Q_1	Q_3	Median	Q_1	Q_3	p-value*
Copy	17.50	14.00	18.00	19.50	14.52	20.00	0.137
Immediate recall	7.00	3.62	7.25	9.75	6.00	10.50	**0.006**
Delayed recall	2.50	0.00	3.00	8.50	5.00	8.25	**-0.001**

*Wilcoxon test
Subtitle: VR = vestibular rehabilitation; TCF-S = Simplified Taylor Complex Figure
Source: Developed by the authors

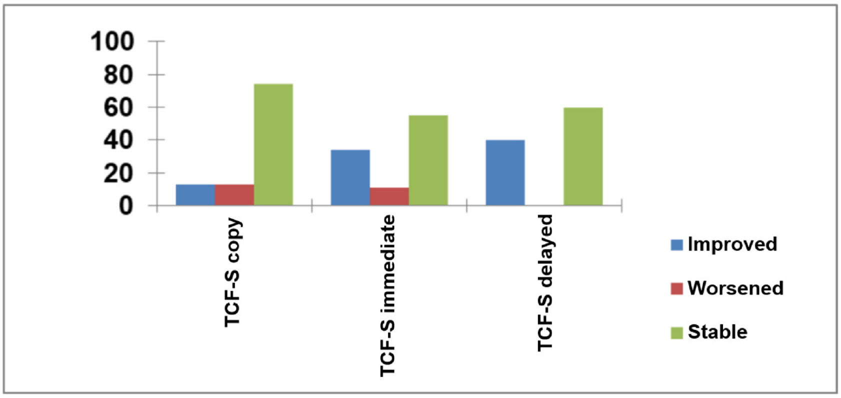

Figure 2. Intra-subject reliable change index of the parameters of the simplified Taylor Complex Figure
Subtitle: TCF-S = Simplified Taylor Complex Figure
Source: Developed by the authors

Neither sex (p = 0.597) nor type of vestibular dysfunction (p = 0.193) was associated with any of the study variables, revealing that these variables were not limiting factors for the improvement of visuospatial function after treatment. Figure 3 illustrates the improvement in visuospatial function using the TCF-S.

DISCUSSION

Visuospatial function improved after VR, mainly in immediate and delayed recall, confirming the findings in the literature[5,8,10,19,20]. Visuospatial function assists the individual in spatial navigation, body awareness, and spatial orientation tasks[5,8,10,19,20]. Vestibulo-ocular reflex is one of the reflexes that actively participates in the cognitive ability called visuospatial function[8,18,19,21,29,30]. This reflex sends information to the vestibular cortex and assists in ocular fixation even with head and body movement, being an essential skill in performing various daily tasks[8,18,19,21,29,30].

The intrasubject analysis using RCI verified improved visuospatial function in copying, immediate recall, and delayed recall tasks. The RCI is used in neuropsychological assessment to compare an individual's test results at two different time points[28]. The analysis considers the instrument reliability data and the standard deviation of a sample similar to that of the evaluated individual to detect changes associated with treatments and interventions[28].

The improvement in visuospatial function observed in this study may be based on communication between the vestibular system and the cortex, more specifically the hippocampus, which is responsible for memory skills and visuospatial function[1-6]. A possible explanation for this finding is that vestibular rehabilitation exercises that use eye fixation activate the superior vestibular pathway through vestibulo-ocular and vestibulo-spinal reflexes, carrying

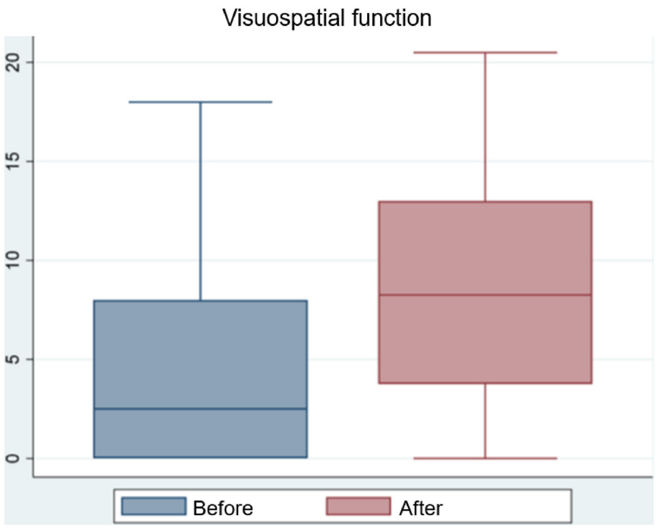

Figure 3. Comparison of the simplified Taylor Complex Figure before and after treatment
Source: Developed by the authors

information to the vestibular cortex and activating, mainly, the hippocampus[1-6,8,19].

The hippocampus is believed to be important for spatial representation processes that depend on the integration of movement signals; it also interacts significantly with areas associated with voluntary motor control, such as the striatum in the basal ganglia[8,9,18,19,21,29,30]. The vestibular system is connected directly with the amygdala and hippocampus, both key components of the limbic system, involved in processing emotions and memory[1-6,8,19]. Studies have shown that vestibular input can modulate activity in the amygdala and hippocampus and that the limbic system can influence vestibular processing[1-6].

Thus, when VR stimulates the vestibular system, the vestibular signal is sent through four main ascending pathways to the hippocampus involved in spatial cognition[8,9,18,19,21,29,30]. The thalamic nuclei, specifically the posterior lateral, posterior ventral, medial, and ventrolateral geniculate nuclei, transmit signals from the vestibular nucleus complex to various cortical areas, including the visual and parietal areas[1-6]. The vestibulo-cerebellar-cortical pathway also transmits vestibular data to the parietal cortex, which, in turn, projects to the hippocampus[1-6]. This interaction between the vestibular system and the hippocampus activates cognitive functions that are coordinated by this structure, including the visuospatial function evaluated in this study[4-6,8,19,29,30].

The mechanisms involved in the association between vestibular dysfunction and cognitive impairment are still unclear[1-6]. Several hypotheses have been studied, among them, vestibular dysfunction as a determinant of atrophy in areas of the cortical vestibular network, including the hippocampus, responsible for memory and visuospatial ability[1,3,4,6,8,10]. Such associations were confirmed by neuroimaging exams that revealed hippocampal atrophy and deficits in spatial navigation tasks in individuals with bilateral vestibular alterations[4-6,8,19,29,30].

Visuospatial function was stable among those in whom it did not improve significantly after VR. It is worth noting that the older adults' TCF-S response results were below expectations in the assessment and reassessment. Some individuals had worse reassessment results in the copy and immediate recall tasks. The participants' TCF-S results below expectations for age and education level can be confirmed in the literature, which highlights the difficulty in visuospatial function in individuals with vestibular dysfunction[1-6,8,19].

Virtually all daily activities involve visuospatial skills, from spatial perception to spatial orientation and route planning; all interaction with the world depends on visuospatial skills[4-6,8,19,29,30]. They involve the activation, retention, and/or manipulation of mental representations and are related to working memory and information processing during the performance of complex cognitive activities[4-6,8,19,29,30].

The visuospatial function is closely linked to the vestibular system, actively participating in cognitive tasks of spatial orientation, spatial memory, and spatial navigation[4-6,8,19,29,30]. Thus, alterations in the vestibular system can impair these tasks and affect other cognitive tasks that require the effective participation of the visuospatial function, such as reading[1,4-6,8,19,29,30]. The findings of this study reinforce the possibility of improving cognitive skills activated in the vestibular cortex through VR[5,8-10,19,20].

This study did not evaluate VR effectiveness, since this is already well defined in national and international literature. When VR stimulates cognitive function in older adults, even indirectly, it can improve cognitive skills, enhance independence and functioning, and diminish the risk of developing cognitive diseases[10,16-19]. Speech-language-hearing studies on the interaction between cognition and otoneurology are necessary for the recognition and scientific advancement of the profession.

Among the limitations of this study, it was not possible to collect control group data or blind the evaluator before and after VR, as one of the researchers assessed, treated, and reassessed the older adults because of the need to avoid exposing them to a larger number of people, given the restrictions imposed by the COVID-19 pandemic. At the time, there were limitations regarding the number of people frequenting the various locations within the health campus, and older adults were considered a risk group. Another point that deserves attention was the difficulty in controlling how participants performed VR exercises at home, which was addressed through communication via mobile phone applications to clarify doubts through audio and video. Moreover, the findings cannot be generalized to the entire population, as they refer to independent older adults without polypharmacy or cognitive impairments.

CONCLUSION

Older adults' visuospatial function improved after VR. This can be explained by the close relationship between the vestibular system and the vestibular cortex, particularly the hippocampus, which is involved in memory and spatial navigation tasks.

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