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Review Article

Cognitive Performance in People with Vestibular Disorders: An Integrative Literature Review

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ABSTRACT

The impact of vestibular disorders on quality of life and the physical, emotional, and social spheres has been widely studied and documented. However, although functional and anatomical relationships have been found between the vestibular system and cortical areas, neuroimaging studies have established that domains like attention, memory, spatial navigation, and orientation would be involved, despite there being few studies investigating cognitive performance. This study aimed to identify and synthesize the available scientific evidence on cognitive performance in people with vestibular disorders and to analyze the methodological quality of the selected articles. An integrative literature review was carried out which surveyed the databases of ProQuest, EBSCO, PubMed, ScienceDirect, Cochrane Library, and SciELO. The studies' methodological quality was assessed using the Downs & Black checklist for randomized and nonrandomized healthcare intervention studies. Altogether, 771 studies were found, of which 5 were selected and analyzed. The results show that the cognitive domains that are studied focus mainly on general cognitive status, visual-spatial skills, executive functions, and attention. Nonetheless, the findings are contradictory due to methodological differences (pathology studied, status of the pathology, instruments used, age of the participants, and lack of control groups, among others).

Keywords:
Vestibular Disorders; Vestibular System; Cognition

Rendimiento cognitivo en personas con patologías vestibulares: Una revisión integradora de la literatura

RESUMEN

El impacto de las alteraciones vestibulares sobre la calidad de vida y los aspectos físico, emocional y social ha sido ampliamente estudiado y documentado. Por el contrario, los estudios sobre rendimiento cognitivo son escasos y con los que se cuenta son principalmente de neuroimagen. Dichos estudios establecen que dominios cognitivos como la atención, memoria, orientación y navegación espacial estarían involucrados. Los objetivos de este estudio fueron: 1) identificar y sintetizar la evidencia científica disponible sobre el rendimiento cognitivo en personas con patologías vestibulares y 2) analizar la calidad metodológica de los artículos seleccionados. Se realizó una revisión integradora de literatura utilizando las bases de datos Proquest, Ebsco, Pubmed, ScienceDirect, Cochrane Library y Scielo. La evaluación de la calidad metodológica se efectuó completando la lista de verificación de estudios aleatorios y no aleatorios de las intervenciones de atención de salud de Downs y Black. De los 771 estudios encontrados, 5 fueron seleccionados y analizados. Los resultados demuestran que los dominios cognitivos estudiados contemplan en mayor medida estado cognitivo general, habilidades visoespaciales, funciones ejecutivas y atención. No obstante, los hallazgos son contrapuestos debido a las diferencias metodológicas (patología estudiada, estado de la patología, instrumento empleado, edad de los participantes, ausencia de grupos controles, entre otros).

Palabras clave:
Enfermedades Vestibulares; Sistema Vestibular; Cognición

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INTRODUCTION

The impact of vestibular disturbances on quality of life and physical, emotional, and social wellbeing has been extensively studied and documented (Agrawal et al., 2009; Herdman et al., 2020; MacDowell et al., 2017; Petri et al., 2017; Vélez León et al., 2010). However, despite the evidence on the anatomo-functional relationship between the vestibular system and certain cortical areas, primarily based on neuroimaging studies (Jang et al., 2018; Kirsch et al., 2016), studies on the impact of vestibular pathologies on cognitive performance remains limited.

It has been described that efferent connections from vestibular nuclei give rise to various pathways (traditionally mentioned are the vestibulo-spinal, vestibulo-collic, vestibulo-ocular, and vestibulo-cerebellar pathways), which establish synaptic connections with multiple structures and systems (Suárez, 2003). However, scientific evidence has also shown that there are projections from the vestibular nuclei to thalamic nuclei, and from there to the cerebral cortex (Gallardo-Flores, 2018; Lopez & Blanke, 2011; Wijesinghe et al., 2015).

Animal studies have demonstrated that the main areas of the thalamus involved are the intralaminar, ventrolateral, and ventrobasal nuclei, as well as the lateral and medial geniculate bodies (Lopez & Blanke, 2011; Wijesinghe et al., 2015). Similarly, it has been documented that the thalamus participates in episodic memory, behavioral flexibility, working memory, and associative memory (Geier et al., 2020; Koenig et al., 2019; Parnaudeau et al., 2018), besides its function as a relay zone to the cerebral cortex.

Furthermore, the evidence supports that certain areas of the cerebral cortex (superior medial temporal area, parietoinsular vestibular cortex, ventral intraparietal area, somatosensory cortex, premotor cortex, hippocampus, parahippocampal gyrus, cingulate gyrus, among others) are linked to projections from vestibular nuclei (Aedo Sánchez et al., 2016; Faúndez A et al., 2019; Jang et al., 2018). In this sense, Dieterich & Brandt (2015) have highlighted that attention, memory, orientation, and spatial navigation are related to vestibular areas. More specifically, other authors have studied the association between the vestibular system and cognitive domains. The general cognitive domain is understood as a set of processes that occur after perceptual processing, involving executive functions, visuospatial skills, attention, and memory, among others (Lavados & Slachevsky, 2013).

Each of these is conceptualized below. Executive functions are defined as the "set of skills involved in regulating, executing, generating, and supervising behavior to achieve complex goals" (Verdejo-García & Bechara, 2010, p. 227). Visuospatial skills are understood as the ability to represent, analyze, and understand spatial organization, object depth, and distances to or between them (Ortega-Leonard et al., 2015). Attention is defined as the "cognitive process that allows the organism to process relevant sensory afferences, thoughts, and actions, while ignoring irrelevant or distracting ones" (Gazzaniga et al., 2009 en Lavados & Slachevsky, 2013, p. 100). Memory is understood as the ability to remember a sequence of visual and/or auditory information (Ballesteros Jiménez, 1999). Verbal fluency is the "ability to create, produce, express, and relate words and know their meaning quickly and effectively" (Velasco-Orozco et al., 2020, p. 29).

Lee et al. (2014) demonstrated cortical activation of areas related to memory after applying galvanic vestibular stimulation in young adults without vestibular disturbances. On the other hand, Jacob et al. (2020) studied the relationship between vestibular function and variation in the morphology of certain brain structures in individuals over 60 years old without specification of vestibular pathology. These authors concluded that vestibular disturbances are associated with a reduction in the total volume of the hippocampus and the entorhinal cortex, as well as with the shape of some subcortical structures, referring to the impact that such disorders could have on orientation, navigation, and spatial memory.

Along the same lines, it was found, through magnetic resonance volumetry, that individuals with acquired chronic bilateral vestibular hypofunction developed significant hippocampal atrophy, leading to difficulties in spatial memory and navigation (Brandt et al., 2005). Schautzer et al. (2003) found similar evidence when studying patients with bilateral neurectomy for type II neurofibromatosis. Moreover, a study carried out on rats suggests that, at least up to approximately one year later, disturbances in spatial memory can be permanent despite possible adaptation of physical symptoms in bilateral vestibular deafferentation (Baek et al., 2010).

Additionally, it has been found that attention, visuospatial abilities, and executive function improve after a vestibular rehabilitation program in young individuals hospitalized for persistent dizziness (Sugaya et al., 2018). In contrast, Bigelow et al. (2015) indicate, based on a national health survey, that performance in verbal memory tests and executive function is not significantly related to vestibular function, but rather to general cognitive status, attention, visuospatial memory, and working memory. Regarding attention, Nascimbeni et al. (2010) report that individuals with unilateral vestibular neuritis have fewer attentional resources during walking compared to the control group. On their part, Zheng et al. (2004), based on unilateral and bilateral vestibular deafferentation in rats, conclude that those subjected to bilateral deafferentation had difficulty in spontaneous object recognition at 3 and 6 months post-surgery.

Considering the findings obtained through neuroimaging techniques and the contrasting results among some studies, it is necessary to review the available scientific literature on performance in specific cognitive domains using cognitive tests, as recent reviews on this topic are scarce. Additionally, there is a need to assess the methodological quality of the studies. For this purpose, an integrative literature review is proposed, as this type of review has been considered a useful tool for synthesizing research on a particular topic and guiding evidence-based practice in health contexts (Souza et al., 2010).

Therefore, the objectives of the present integrative review are (1) to identify and synthesize the available scientific evidence on cognitive performance in individuals with vestibular pathologies and (2) to analyze the methodological quality of the selected articles.

METHODOLOGY

The researchers conducted an integrative literature review on cognitive performance in individuals with vestibular pathologies. The study was developed following the stages proposed for the elaboration of such reviews: 1) Formulation of the guiding question, 2) Literature search or sampling, 3) Data collection, 4) Critical analysis of the included studies, 5) Discussion of the results, 6) Presentation of the integrative review (Souza et al., 2010). Additionally, the study design was based on the guidelines and recommendations of Preferred Reporting Items for Systematic Reviews and Meta-Analyses Protocols (PRISMA-P) (Moher et al., 2015).

Search Strategy

The development of the review was based on the question: "What is the cognitive performance of individuals with vestibular pathology in cognitive tests compared to healthy individuals?"

The review was based on the search for studies published in the Proquest, Ebsco, Pubmed, ScienceDirect, Cochrane Library, and Scielo databases. The search was carried out by the authors between August 2021 and December 2022, using combinations of terms in English available in the Medical Subject Heading (MeSH), and their equivalents in Spanish and Portuguese obtained from the Health Sciences Descriptors (*Descriptores en Ciencias de la Salud*, or DeCS). The descriptors were combined using the boolean operators "OR" and "AND" (Table 1).

Selection Criteria and Data Extraction

The search considered articles that met the following inclusion criteria: a) published in English, Spanish, or Portuguese; b) published not earlier than the year 2011; c) conducted in humans with vestibular problems unrelated to other types of pathologies; d) no age range restriction; and e) cohort studies, non-randomized clinical trials, and randomized trials. On the other hand, exclusion criteria included: a) studies unrelated to the objective and research question of this study; b) inclusion of other conditions or pathologies related to cognitive and/or linguistic impairments (stroke, traumatic brain injury, dementia, Parkinson's disease, hearing impairment, among others); c) works duplicated between databases or with irrelevant information; d) written in languages other than those specified; and e) systematic reviews, meta-analyses, and single-case or case series studies.

The search resulted in 771 potential articles being identified based on the combination of descriptors and inclusion criteria outlined above. The article analysis process was carried out in three stages; the first involved reading the titles and abstracts, during which duplicate, irrelevant, or unrelated articles were eliminated. The second eligibility stage involved the thorough reading of the articles, determining whether they addressed the research question, and excluding articles that did not meet the previously established criteria. Finally, the third step involved the analysis of the methodological quality of the selected articles by two of the researchers, according to the checklist for randomized and non-randomized studies of healthcare interventions (Downs & Black, 1998). The checklist was adapted for non-randomized studies, reducing the evaluation from 27 items to 17 criteria (Freke et al., 2016). That is, for randomized studies, a total score of 27 points was considered, while non-randomized research had a maximum score of 17 points (excluding items 4, 13, 14, 15, 17, 19, 22, 23, 24, and 27). Based on this checklist, studies were considered of high quality with a score equal to or higher than 10 points. In case of disagreement, the researchers reviewed the item together to reach a consensus.

Table 1. Descriptors used for the search in electronic databases.

English (MeSH)	Spanish (DeCS)	Portuguese (DeCS)
Vestibular Diseases AND Cognition	Enfermedades Vestibulares AND Cognición	Doenças Vestibulares AND Cognição
Vestibular Diseases AND Cognition Disorders	Enfermedades Vestibulares AND Trastornos del Conocimiento	Doenças Vestibulares AND Transtornos Cognitivos
Vestibular Diseases AND Memory	Enfermedades Vestibulares AND Memoria	Doenças Vestibulares AND Memória
Vestibular Diseases AND Attention	Enfermedades Vestibulares AND Atención	Doenças Vestibulares AND Atenção
Vestibular Diseases AND Language	Enfermedades Vestibulares AND Lenguaje	Doenças Vestibulares AND Linguagem
Vestibular Diseases AND Executive Function	Enfermedades Vestibulares AND Función Ejecutiva	Doenças Vestibulares AND Função Executiva
Vestibulocochlear Nerve Diseases AND Cognition	Enfermedades del Nervio Vestibulococlear AND Cognición	Doenças do Nervo Vestibulococlear AND Cognição
Vestibulocochlear Nerve Diseases AND Cognition Disorders	Enfermedades del Nervio Vestibulococlear AND Trastornos del Conocimiento	Doenças do Nervo Vestibulococlear AND Transtornos Cognitivos
Vestibulocochlear Nerve Diseases AND Memory	Enfermedades del Nervio Vestibulococlear AND Memoria	Doenças do Nervo Vestibulococlear AND Memória
Vestibulocochlear Nerve Diseases AND Attention	Enfermedades del Nervio Vestibulococlear AND Atención	Doenças do Nervo Vestibulococlear AND Atenção
Vestibulocochlear Nerve Diseases AND Language	Enfermedades del Nervio Vestibulococlear AND Lenguaje	Doenças do Nervo Vestibulococlear AND Linguagem
Vestibulocochlear Nerve Diseases AND Executive Function	Enfermedades del Nervio Vestibulococlear AND Función Ejecutiva	Doenças do Nervo Vestibulococlear AND Função Executiva
Bilateral Vestibulopathy AND Cognition	Vestibulopatia Bilateral AND Cognición	Vestibulopatia Bilateral AND Cognição
Bilateral Vestibulopathy AND Cognition Disorders	Vestibulopatia Bilateral AND Trastornos del Conocimiento	Vestibulopatia Bilateral AND Transtornos Cognitivos
Bilateral Vestibulopathy AND Memory	Vestibulopatia Bilateral AND Memoria	Vestibulopatia Bilateral AND Memória
Bilateral Vestibulopathy AND Attention	Vestibulopatia Bilateral AND Atención	Vestibulopatia Bilateral AND Atenção
Bilateral Vestibulopathy AND Language	Vestibulopatia Bilateral AND Lenguaje	Vestibulopatia Bilateral AND Linguagem
Bilateral Vestibulopathy AND Executive Function	Vestibulopatia Bilateral AND Función Ejecutiva	Vestibulopatia Bilateral AND Função Executiva
“Vestibular System Syndrome” AND Cognition	Síndrome Sistema Vestibular AND Cognición	Síndrome Sistema Vestibular AND Cognição
“Vestibular System Syndrome” AND Cognition Disorders	Síndrome Sistema Vestibular AND Trastornos del Conocimiento	Síndrome Sistema Vestibular AND Transtornos Cognitivos
“Vestibular System Syndrome” AND Memory	Síndrome Sistema Vestibular AND Memoria	Síndrome Sistema Vestibular AND Memória
“Vestibular System Syndrome” AND Attention	Síndrome Sistema Vestibular AND Atención	Síndrome Sistema Vestibular AND Atenção
“Vestibular System Syndrome” AND Language	Síndrome Sistema Vestibular AND Lenguaje	Síndrome Sistema Vestibular AND Linguagem
“Vestibular System Syndrome” AND Executive Function	Síndrome Sistema Vestibular AND Función Ejecutiva	Síndrome Sistema Vestibular AND Função Executiva

Synthesis of Data

The selected articles were analyzed according to the following data: country, study objective, study type, sample size (n), mean age of the sample, included vestibular disturbances, diagnostic examination or assessment, evaluated cognitive skills, applied instrument and/or test, and main results.

RESULTS

Out of the initial 771 articles found through the databases, 198 were excluded due to being duplicates. After reading the title and abstract, 564 articles were eliminated for the following reasons: a) being unrelated to the objective and/or research question, b) being systematic reviews, and c) being written in a language other than those specified. After reading the full text of the 9 articles evaluated for eligibility, 5 were selected for the present review (Balci et al., 2018; Caixeta et al., 2012; Deroualle et al., 2019; Jandl et al., 2015; Moser et al., 2017). The remaining 4 articles were excluded due to either not directly relating to the stated objective of this research, or drawing conclusions from studies on individuals without vestibular disturbances, i.e., healthy subjects (Figure 1).

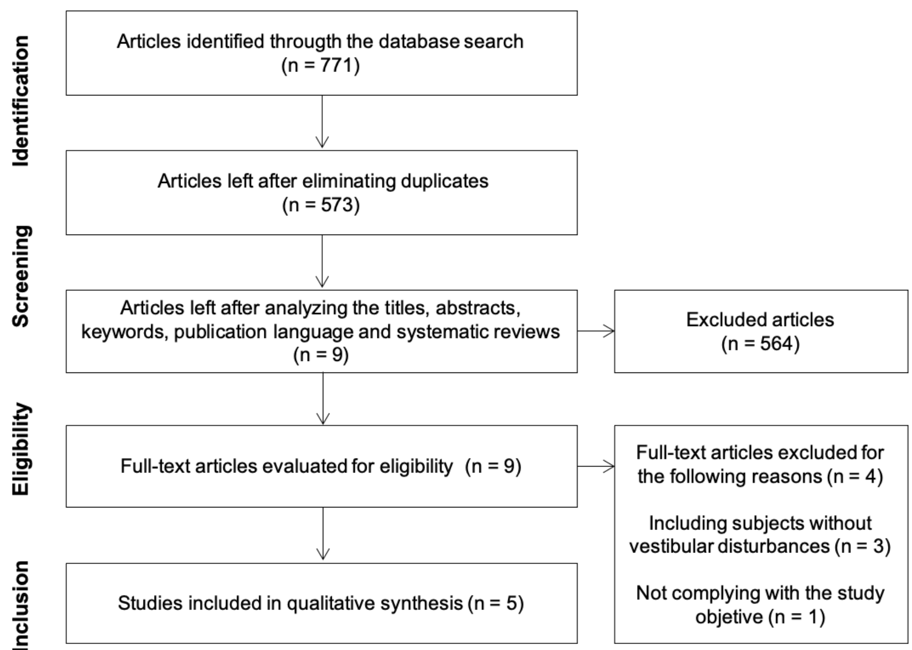

Figure 1. Flow diagram representing the article selection process.

Table 2 summarizes the selected studies, showing the year of publication, country, objective, characteristics of the participants, and procedures used for the diagnosis of the studied vestibular pathology. Meanwhile, Table 3 presents the main results according to the cognitive skills that were studied, instruments, and/or procedures applied.

Concerning the year of publication, the first article corresponds to Caixeta, which was published in 2012. The other articles, however, are more recent, being published between 2015 and 2019. In addition, most publications were conducted in Europe: Switzerland, Germany, France, Turkey, and also in Brazil.

The sample size for the studied group ranged from 23 to 76 participants, while for the control group, consisting of individuals without vestibular pathology, it varied between 23 and 31 participants. It is worth noting that one study did not include a control or reference group. The ages of individuals with vestibular pathologies ranged from 27 to 75 years, while healthy individuals were between 30 and 72 years. There is also variability among the vestibular pathologies that were analyzed, with individuals with vestibular neuritis (n = 2) and Ménière's disease (n = 2) being more frequent, followed by acoustic neuroma (n = 1), unspecified chronic peripheral vestibular deficit (n = 1), bilateral vestibulopathy due to ototoxicity (n = 1), and vestibular migraine (n = 1). Regarding the tests used to diagnose the studied vestibular pathologies, 3 studies used one of the following assessments: audiometry, bithermal caloric testing, rotary chair testing, vestibular evoked myogenic potential (VEMP), video head impulse test (vHIT), subjective visual vertical (SVV), or dynamic visual acuity test (DVA). Only 2 articles did not specify the assessments being used, referring to general medical or otoneurological tests instead.

Table 2. Characteristics of the studies and samples.

Study	Country	Type of Study	Objective	Studied Group		Control Group		Vestibular Pathologies Included	Test used to Diagnose the Vestibular Pathology
				N	Age	N	Age		
Moser et al. (2017)	Switzerland	Non-Experimental, Cross-Sectional, Analytic Study	To investigate the effects of acute peripheral vestibular deficit on the spatial representation of numbers.	43	44.0 years +/- 17.2 S.D.	28	46.5 years +/- 16.8 S.D.	Acute peripheral vestibular deficit due to viral infection (vestibular neuritis).	Bithermal Caloric Testing Rotary Chair Testing cVEMP vHIT SVV DVA
Caixeta et al. (2012)	Brazil	Cross-Sectional, Contemporary Cohort Study	To assess the relationship between cognitive processing and body balance in elderly patients with chronic peripheral vestibular disease.	76	69 years +/- 6.21 S.D.	NR	NR	Chronic peripheral vestibular disease with a minimum evolution of 3 months.	Medical and speech-language pathology assessments, without further specification.
Jandl et al. (2015)	Germany	Non-Experimental, Cross-Sectional, Analytic Study	To identify the brain activity related to events using functional magnetic resonance imaging during spatial navigation and visual memory tasks in patients with bilateral vestibulopathy.	23	65 years +/- 10.4 S.D.	26	63.7 years +/- 9.4 S.D.	Bilateral vestibulopathy due to antibiotic ototoxicity, idiopathic causes, sequential vestibular neuritis, and Ménière's disease.	Bithermal Caloric Testing vHIT SVV VEMP (no specification of cervical or ocular)
Deroualle et al. (2019)	France	Non-Experimental, Cross-Sectional, Analytic Study	To clarify the vestibular contributions to visuospatial perspective-taking.	23	51 years +/- 12 S.D.	23	52 years +/- 12 S.D.	Unilateral vestibular neurectomy due to vestibular schwannoma or Ménière's disease.	Audiometry Bithermal Caloric Testing Rotary Chair Testing vHIT SVV
Balci et al. (2018)	Turkey	Cross-sectional, Descriptive, Casa/Control Study	To compare the balance and cognition of patients with vestibular migraine, migraine without a history of vertigo, and healthy subjects, and examine the effects of disability level on these functions.	64	41.32 years +/- 9.53 S.D.	31	37.63 years +/- 7.18 S.D.	Vestibular migraine.	Otoneurologic assessments (unspecified) and confirmation of diagnostic criteria for migraine according to Neuhauser VAS

Two of the articles addressed the assessment of cognitive performance through screening tests such as the Mini Mental State Examination (MMSE) and Montreal Cognitive Assessment (MoCA). More specifically, and independently in each study, executive functions and spatial orientation were evaluated using Random Number Generation (RNG) and the Stroop Test (ST), attention was assessed through the Stroop Test (ST) and virtual reality tasks recorded by magnetic resonance imaging (MRI), visuospatial skills through the Clock Test (CT) and tasks of visual detection and mental rotation of 3D objects through virtual games, verbal fluency through the Verbal Fluency Test (VFT), and visual memory using MRI during virtual reality tasks.

Table 3. Main results according to the studied cognitive skills and instruments applied.

Study	Assessed Function and/or Skill	Applied Instruments and/or Cognitive Tests	Other Tests Applied	Main Results
Moser et al. (2017)	Executive Functions and Spatial Orientation	Random Number Generation task (RNG)	-	The studied group showed greater redundancy in numerical sequences compared to the control group, which were generated randomly under dynamic conditions. No differences were observed between the studied and control groups regarding the magnitude of the generated numbers, indicating no bias in the numerical space, both in static and dynamic conditions.
Caixeta et al. (2012)	General Cognitive Performance	Mini Mental Test (MMSE)	TUG TUGm	35.5% obtained a score below the normal range, consistent with cognitive impairment. There was a negative correlation between MMSE and TUG/TUGm.
	Visuospatial Abilities	Clock Test (CT)	DGI	No disturbances were observed in visuospatial abilities. Negative correlation between the CT and DGI tests.
	Verbal Fluency	Verbal Fluency Test (VFT).	DGI BBS	Older adults with higher levels of education obtained results that suggested cognitive impairments. Positive correlation with DGI and BBS tests.
Jandl et al. (2015)	General Cognitive Performance	Montreal Cognitive Assessment (MoCA)	-	The scores did not differ between the studied and control groups.
	Sustained Attention and Visual Memory	MRI during virtual reality tasks	-	Patients with vestibular hypofunction, compared to the control group, exhibited higher cerebellar activity during sustained attention tasks than during visual memory tasks. There was no difference in response latency between both groups for either test.
Deroualle et al. (2019)	Visuospatial Abilities	Tasks involving visual detection and mental rotation of 3D objects through virtual gaming. Questionnaire about strategies used	-	The studied group exhibited longer response times than the control group in third-person perspective tasks, but not in first-person perspective tasks. Patients who underwent left neurectomy exhibited a significantly longer response time than the control group. Response times did not correlate with the neurinoma grade.
Balci et al. (2018)	Executive Functions Attention	Stroop Test (ST)	Balance Evaluation (BESTest)	The group with vestibular migraine obtained lower scores than the control group in the Stroop Test (ST), but not compared to the group of patients with migraine (without vertigo). There was a negative correlation between the Stroop Test (ST) and BESTest for the vestibular migraine group compared to the migraine (without vertigo) and control groups.

Regarding the main results reported by the studies, the MMSE indicates that overall cognitive performance is impaired in 35.5% of the individuals, as they obtained a score below the normal range. Additionally, it is reported that subjects with lower MMSE scores exhibit longer walking times in gait tests when a recall task is incorporated. On the other hand, the results of the MoCA test show no score differences between individuals diagnosed with bilateral vestibulopathy and those with normal vestibular function.

Table 4. Assessment of methodological quality using the Downs and Black checklist.

Criteria	Moser et al. (2017)	Caixeta et al. (2012)	Jandl et al. (2015)	Deroualle et al. (2019)	Balci et al. (2018)
1. Is the hypothesis/aim/objective of the study clearly described?	1	1	1	1	1
2. Are the main outcomes to be measured clearly described in the Introduction or Methods section?	1	1	1	1	1
3. Are the characteristics of the subjects included in the study clearly described?	1	0	1	1	1
4. Are the distributions of principal confounders in each group of subjects to be compared clearly described?	0	0	0	0	0
5. Are the main findings of the study clearly described?	1	1	1	1	1
6. Does the study provide estimates of the random variability in the data for the main outcomes?	0	0	0	0	0
7. Have all important adverse events that may be a consequence of the intervention been reported?	ND	ND	ND	ND	ND
8. Have the characteristics of subjects lost to follow-up been described?	ND	ND	ND	ND	ND
9. Have actual probability values been reported (e.g. 0.035 rather than <0.05) for the main outcomes except where the probability value is less than 0.001?	1	0	1	1	1
10. Were the subjects asked to participate in the study representative of the entire population from which they were recruited?	1	1	0	1	1
11. Were those subjects who were prepared to participate representative of the entire population from which they were recruited?	0	0	0	0	0
12. If any of the results of the study were based on "data dredging" (misuse of data analysis to present them as statistically significant), was this made clear?	1	1	1	1	1
13. Were the statistical tests used to assess the main outcomes appropriate?	1	1	1	1	1
14. Were the main outcome measures used accurate (valid and reliable)?	1	1	1	1	1
15. Were the subjects in different intervention groups (trial and cohort studies) or cases and controls (case and control studies) recruited from the same population?	1	0	1	1	1
16. Was there adequate adjustment for confounding in the analyses from which the main findings were drawn?	1	0	1	1	1
17. Were losses of subjects to follow-up taken into account?	ND	ND	ND	ND	ND
Total	11	7	10	11	11

Concerning the assessment of specific cognitive abilities, it is noteworthy that for executive functions (n = 2) and spatial orientation (n = 1), individuals with acute peripheral vestibular deficit exhibited reduced inhibition of stereotyped responses, as they showed greater redundancy in their number sequences compared to the control group in RNG tasks; however, no bias in numeric space is evident. Regarding attention (n = 2), the Stroop Test showed significantly lower scores in the group of patients with vestibular migraine compared to the control group, but not compared to the group of patients who only presented migraine (without vertigo). Furthermore, it was found that individuals with the lowest scores on the Stroop Test were at greater risk of falls during the walking conditions in the Dynamic Gait Index; this was more evident for patients with vestibular migraine compared to the migraine (without vertigo) group and control group. In virtual reality tasks recorded by MRI, patients with vestibular hypofunction showed greater cerebellar activity in sustained attention tasks than in visual memory tasks, compared to the control group. However, there was no difference in response latency between both groups for either test.

On the other hand, concerning visuospatial abilities (n = 2), the findings showed that individuals with chronic peripheral vestibular deficit did not exhibit issues in the Clock Test (CT). Nevertheless, it was proved that individuals with lower scores on this test had greater difficulty in walking tests and were at risk of falls. In the same vein, another study revealed that patients who underwent neurectomy required more response time in third-person perspective tasks, but not when the task was in first person; this was assessed through a virtual ball-throwing game. With regards to verbal fluency (n = 1), the results report that older adults with a higher level of education manifested difficulty in word recall. Additionally, subjects with better scores on the verbal fluency test showed better scores on walking and balance tests.

Finally, the methodology of the selected studies was analyzed using the modified Downs and Black checklist (Freke et al., 2016) as presented in Table 4. Four studies scored 60% or more (10/17 points), thus considered of high quality (Balci et al., 2018; Deroualle et al., 2019; Jandl et al., 2015; Moser et al., 2017), while one study (Caixeta et al., 2012) scored below 60% of the total score. This score is explained by the following reasons: the characteristics of the participants were not clearly described (e.g., specific vestibular diagnosis, instruments used for assessment), a control group was not considered to contrast the findings of the studied group, and confounding factors were not described.

DISCUSSION

The objectives of this integrative literature review were 1) to identify and synthesize available scientific evidence on cognitive performance in individuals with vestibular pathologies and 2) to analyze the methodological quality of the selected articles. Only five studies met the inclusion criteria, despite a growing body of current literature suggesting that the vestibular system substantially impacts areas of the thalamus and cerebral cortex. This evidence has mainly been obtained through neuroimaging techniques in animals or healthy individuals (Bigelow et al., 2015; Dieterich & Brandt, 2015; Gallardo-Flores, 2018; Lopez & Blanke, 2011; Wijesinghe et al., 2015). The results and conclusions of this review specifically stem from research on individuals with vestibular disorders such as vestibular neuritis, acoustic neuroma, Ménière's disease, chronic peripheral vestibular deficit, bilateral vestibulopathy due to ototoxicity, and vestibular migraine. Current recommendations, derived from the International Classification of Vestibular Disorders (Bisdorff et al., 2015), suggest considering a layered approach to establish standardized inclusion criteria in research contexts. However, the reviewed studies do not specify relevant inclusion parameters beyond diagnosis, such as the temporal profile of signs and symptoms (acute or chronic state of the condition, number of episodes, duration of vestibular rehabilitation, among others). It is crucial to define and/or delimit these aspects in future research addressing vestibular disturbances, even when the same pathology is being studied.

General cognitive performance was assessed using screening tests in 2 studies. One study applied the Mini-Mental State Examination (MMSE), obtaining scores below the normal range in individuals with chronic peripheral vestibular deficit, which is indicative of cognitive impairment. However, these results were not contrasted with a control group. Additionally, certain structural and psychometric deficits have been identified in the MMSE (Broche-Pérez, 2017; Carnero-Pardo, 2014). The other study used the Montreal Cognitive Assessment (MoCA) and found no differences between the control group and the studied group, which was composed of individuals with bilateral vestibulopathy, vestibular neuritis, and Ménière's disease. Given that screening tests were used, it would have been advisable to use other instruments meant for specific abilities, or neuropsychological tests that delve deeper into cognitive performance in its various domains, for example, the Addenbrooke's Cognitive Examination-Revised (ACE-R) (Torralva et al., 2011; Véliz García et al., 2020) and the NEUROPSI battery (Marreros-Tananta & Guerrero-Alcedo, 2022; Ostrosky-Solís et al., 1998). It is recommended to use instruments with greater psychometric robustness for future research.

The cognitive domains studied in the selected articles are primarily executive functions, visuospatial skills, and attention, while visual memory, verbal fluency, and spatial orientation are explored to a lesser extent. Executive functions were evaluated in individuals with vestibular migraine and vestibular neuritis, using the Stroop test and the Random Number Generation (RNG) task. In the latter, individuals were asked to produce a sequence of random numbers at the pace indicated by a metronome under static (straight head) and dynamic (rhythmic head turns) conditions, following the paradigm of Loetscher & Brugger, (2007). In the first case, although the group with vestibular migraine had a worse performance than the control group, no difference was found when compared to the migraine-only group (without vertigo). The differential factor in the control group was the migraine per se. No significant differences were observed between groups in the second case. The Stroop test is a neuropsychological instrument that assesses only inhibitory control; therefore, other aspects of executive function such as alternation and inhibition, working memory, conceptualization, and abstraction were not addressed. For the analysis of executive functions, it would be better to use the INECO Frontal Screening (IFS) as it is a more comprehensive evaluation, with acceptable psychometric properties and diagnostic accuracy (Ihnen et al., 2013). These findings are consistent with the conclusions of Bigelow et al. (2015), who report that difficulties in executive functions are significantly more common among individuals with vestibular vertigo compared to the general population. It is worth noting that the data were obtained from a national health survey of the US population. Additionally, they contrast with the results of Sugaya et al. (2018), who indicate that executive functions improve in individuals hospitalized for persistent dizziness after vestibular rehabilitation.

The data are contradictory among studies regarding visuospatial skills, which were assessed using the Clock Test (CT) for individuals with chronic vestibular deficit and tasks involving mental rotation of 3D objects for subjects with vestibular neurectomy. Thus, in some studies, the CT did not show disturbances, while others concluded that there was a longer response time in tasks involving visual detection and mental rotation through virtual gaming. These differences can be explained by the diversity of pathologies, the different instruments and/or procedures used for evaluation, and the absence of a control group, among other factors.

Attention was assessed in individuals with bilateral vestibulopathy, vestibular neuritis, and Ménière's disease through virtual reality tasks and in individuals with vestibular migraine using the Stroop test. For the former case, the findings indicate greater cerebellar activity in sustained attention tasks, while for the latter case, lower scores were obtained in the Stroop test compared to a control group. However, the scores were not lower than the group of individuals with migraine only (without vertigo). The Stroop test primarily evaluates executive functions through inhibitory control (Golden, 1994; Rodríguez Barreto et al., 2016), therefore, it does not assess attention, which has been linked to vestibular areas (Bigelow et al., 2015; Dieterich & Brandt, 2015; Nascimbeni et al., 2010).

Research has been conducted on individuals with vestibular neuritis, bilateral vestibulopathy, and Ménière's disease to evaluate visual memory and spatial orientation; however, these studies did not employ neuropsychological tests. Similarly to other cognitive skills, it would be key to study them using specific neuropsychological instruments, as the data found through MRI in virtual reality tasks and random number generation tasks are still too limited to draw conclusions.

As for verbal fluency, which was studied in individuals with chronic peripheral vestibular disease, the results indicate that older adults with a higher level of education showed disturbances that suggest cognitive impairment, compared to individuals with a lower level of education. This was determined based on the findings and conclusions of the authors, which indicate that 21.1% of participants with a higher educational level named up to 13 animals (with the cutoff score being 13 animals per minute for individuals with more than 9 years of schooling). In contrast, 15.8% of individuals with a lower educational level named between 0 and 8 animals (the cutoff being 9 animals per minute for people with less than 9 years of formal education). Previous evidence is contradictory, as both education and age are considered relevant factors affecting cognition (Samper Noa et al., 2011; Santos et al., 2014). Moreover, the analytical process leading to the conclusions is deemed questionable.

Regarding the assessment of methodological quality, according to the checklist for randomized and non-randomized studies of healthcare interventions (Downs & Black, 1998; Freke et al., 2016), most articles are considered of good quality. Nonetheless, some aspects need to be improved such as the information available on participant characteristics, the control of confounding factors (such as education and age), the use of more specific assessment instruments, and the incorporation of a control group to contrast the findings, among others.

There are three areas where this review presents limitations. Firstly, the selected articles were not assessed for risk of bias. Secondly, the analyzed studies display some issues that threaten internal validity, such as the lack of specification of the education level and age of the participants, the type of tests used, and the absence of a control group in some cases. Finally, the findings exhibit a lack of depth regarding the diagnostic and balance tests that were employed. Despite the aforementioned limitations, this work has notable strengths. One example is the incorporation of databases that are considered among the most important and/or used in health sciences (PubMed, Proquest, Ebsco, ScienceDirect, Cochrane Library, and Scielo). Similarly, the use of the PRISMA-P protocol and the application of the Downs and Black checklist facilitated the selection of studies. Lastly, considering publications written in English, Portuguese, and Spanish allowed for an expanded compilation of information.

CONCLUSION

Based on the analysis of the reviewed articles, it can be concluded that cognitive performance has been studied in isolated vestibular pathologies (vestibular neuritis, acoustic neuroma, Ménière's disease, chronic peripheral vestibular disease, bilateral vestibulopathy due to ototoxicity, and vestibular migraine) without considering common parameters that allow for the identification of standardized inclusion criteria. Similarly, diverse methodologies and instruments have been used in the research, which explains the variability of the results, even when studying the same condition. Furthermore, the cognitive domains that are analyzed are mainly general cognitive status, visuospatial skills, executive functions, and attention, which are assessed using screening tests. Spatial orientation, visual memory, and verbal fluency have been studied to a lesser extent. The findings are contradictory due to methodological differences (studied pathology, acute/chronic state of the pathology, participants' age and education level, lack of control groups, and instruments that do not assess specific cognitive domains thoroughly). Finally, concerning the evaluation of the methodological quality, it can be concluded that the quality of the articles is good, although there are aspects to improve such as providing more detailed descriptions of the participant characteristics, controlling confounding factors such as education level and age, and using assessment instruments that are more specific for each cognitive domain, among others.

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