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Diagnostic Audio Vestibular Assessment in mild traumatic brain injury

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Abstract

Aims
The aims of this scoping review are to 1) determine the nature and extent to which diagnostic audio vestibular assessments have been utilised in the diagnosis and management of mild traumatic brain injury (mTBI) and 2) if there is evidence that they should be regularly included in routine assessment following mild traumatic brain injury (mTBI). Additionally, it will serve to map and summarise the available evidence as well as inform future research.

Methods
Adult participants over 18 years of age, with a diagnosis of mild traumatic brain injury who underwent audiological/vestibular interventions were included in the study. This review followed the Joanna Briggs Institute (JBI) scoping review methods manual and the PRISMA-ScR extension for scoping reviews.

Results
A total of 9 studies including 1,782 participants met the criteria for inclusion. The most common study design was case control (n=7), followed by cross sectional (n=2).

Discussion
Vestibular and oculomotor testing shows great promise in diagnosing mTBI with the possibility of cost-effective methods for assessment. There is limited research in this field and further investigations are needed to ascertain the effectiveness of oculomotor and vestibular testing in patients with concussion.

Introduction

Traumatic brain injury (TBI) represents a substantial burden on healthcare systems worldwide with reported annual incidence rates of up to 849 in every 100,000 people in the European population[1]. Many patients that suffer with a TBI report physical, cognitive, and behavioural symptoms in the time following their trauma[2]. A TBI can be caused by mechanical force to the cranium and or/body, where the head and brain is shaken quickly back and forth and may be accompanied by a temporary state of unconsciousness[3]. In the adult population, falls and motor-vehicle accidents are the leading

Official Journal of the Irish Medical Organisation

Ir Med J; May 2024; Vol 117; No. 4; P957
23rd May, 2024

causes of head injury with younger adults inflicting a larger number of head injuries due to sport related incidents[4]. Mild TBI (mTBI), or concussion as it is more commonly known, is the most common type of TBI and can account for up to 75% of cases[5]. Dizziness is a commonly reported symptom following a mild traumatic brain injury. There can be multiple pathological causes for dizziness following a mild traumatic brain injury and this makes it challenging to diagnose[6]. Balance problems can be central or peripheral in origin. At present, the preferred vestibular test battery for diagnosing concussion patients is unclear. Audiology may play an important part in concussion assessment and management due to the skill set and knowledge required to conduct vestibular assessments. Objective diagnostic vestibular assessment is primarily conducted in specialised clinical and laboratory settings, however there are methods of testing which could be implemented outside of these locations.

The objective of this scoping review is to firstly determine the nature and extent to which diagnostic audio/vestibular assessments have been utilised in the diagnosis and management of mild traumatic brain injury and secondly investigate available evidence to include these in routine assessment following mTBI. Additionally, it will serve to map and summarize the available evidence as well as inform future research.

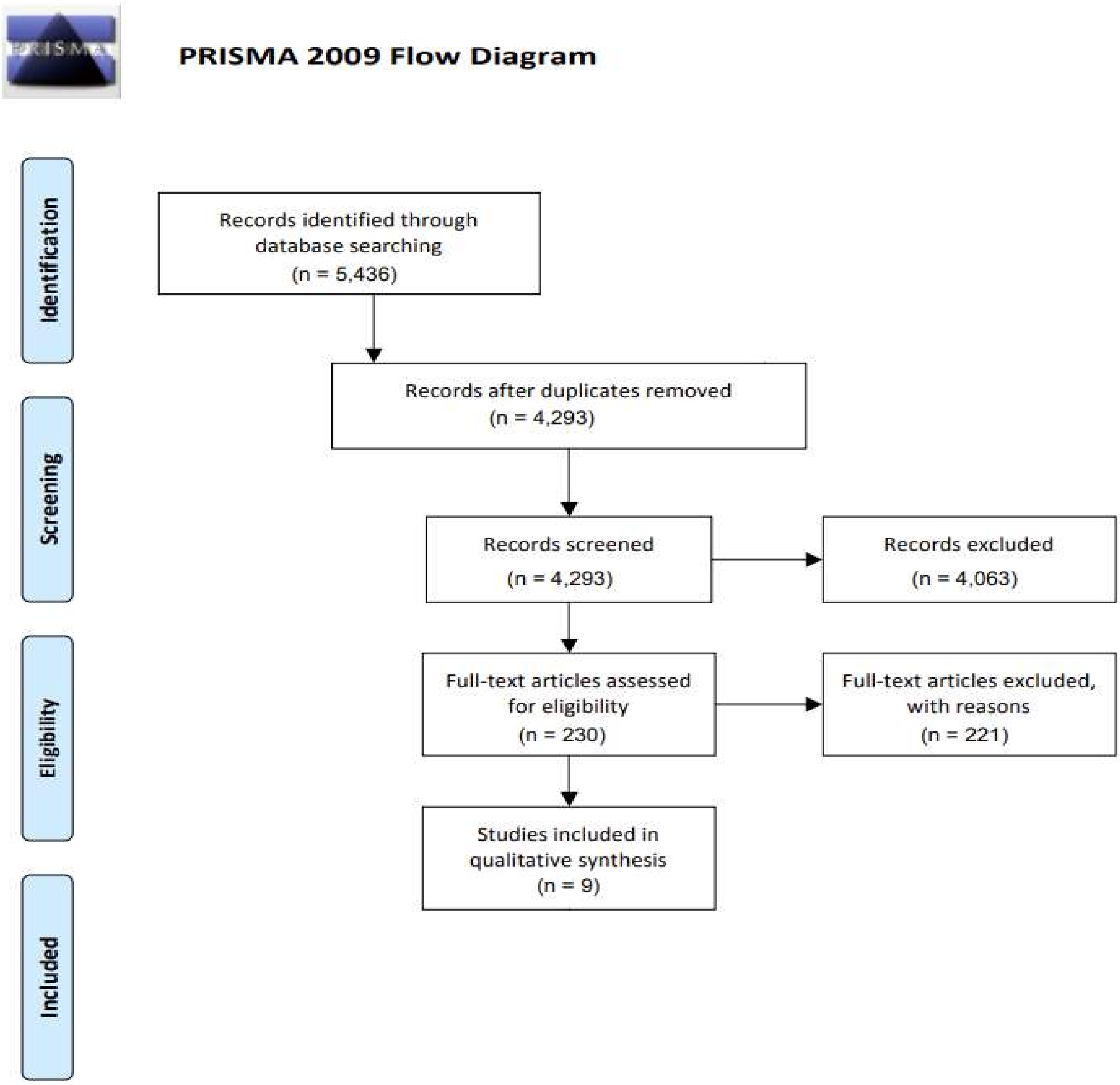
A previous scoping review by Quintana et al. (2021)[6] investigated the role of vestibular and oculomotor assessment strategies and outcomes following sports-related concussion. This review will differ, as it includes participants over the age of 18 years, mild traumatic brain injury by any mechanism and includes audiological assessment strategies.

Methods

The Scoping Review (ScR) followed the Joanna Briggs Institute Manual for Evidence Synthesis methodology, in addition to the Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA) extension statement. Prior to commencing the librarian at University College Cork (UCC) was contacted to advise on creating a comprehensive search strategy. The search strategy was designed to locate both published and unpublished studies. An initial limited search of MEDLINE and CINAHL was undertaken to identify articles on the topic. The text words contained in the titles and abstracts of relevant articles, as well as index terms used to describe the articles were consulted to develop a full search strategy for CINAHL, Web of Science, PubMed and Embase. The search strategy, including all identified keywords and index terms, were adapted for each included database and information source. The reference list of all included sources of evidence was screened for additional studies. Database searching took place from December 2021 to February 2022. Studies published in full text; English Language were included in addition to studies published since database inception to February 2022.

Ir Med J; May 2024; Vol 117; No. 4; P957
23rd May, 2024

Eligibility criteria was defined using the Population, Concept, Context (PCC) tool. The population included adults diagnosed with a recent mild traumatic brain injury and the concept was an investigation of the role of audio vestibular assessment for this population. The search was not limited by location, gender or setting. The search terms were considered in terms of their relevance to each separate element of the research question. If the patient group, intervention, or outcome measures did not meet the specified inclusion criteria they were excluded from the review.



The following exclusion criteria was implemented: paediatric population and no formal diagnosis of mild traumatic brain injury. All papers identified were imported to EndNote reference management software and duplicates removed. The 4,293 papers identified from the search were evaluated for their relevance against the inclusion/exclusion criteria. All research methods were considered for

Official Journal of the Irish Medical Organisation

Ir Med J; May 2024; Vol 117; No. 4; P957
23rd May, 2024

inclusion in this scoping review. The abstracts of articles were screened based on the primary inclusion/exclusion criteria. The remaining 230 papers were analysed by reading the full text and removing papers not meeting inclusion criteria.

Figure 1: Prisma Flow Diagram

Results

Results are displayed as per the recommendations for data extraction, analysis and presentation for scoping reviews[8]. Nine studies were identified for inclusion in the review. Table 1 shows results of the 9 studies included.

Author	Year	Location	Age	Total no. of subjects	Type of study	Interventions used	Significant tests
Balaban et al.	2016	USA	18-45 years	300	Case-control	Oculomotor Vestibular Reaction Time test battery	Anti-saccades HIT gain and symmetry Predictive saccades
Carrick et al.	2020	USA	18-65 years	635	Retrospective case-control	mCTSIB Head positional tests	mCTSIB Head positional tests
Cheever et al.	2017	USA	21.7 +/- 3.5 20.5 +/- 2.3 20.5 +/- 2.7 years	89	Prospective cohort	Saccades Smooth Pursuit Optokinetic Gaze stabilization NPC King-Devick	Smooth Pursuit Gaze stabilization Optokinetic NPC King-Devick
Cifu et al.	2015	USA	23.2 mean age	86	Case-control	Saccades Fixation Smooth Pursuit	Saccades Smooth Pursuit
Cochrane et al.	2019	USA	18-24 years	115	Case-control	Predictive saccade Horizontal/Vertical saccades Smooth pursuit Antisaccades Optokinetic Visual/Auditory reaction time Dual task	Horizontal/Vertical saccades Smooth pursuit Visual reaction times Dual reaction times
Hoffer et al.	2017	USA	18-45 years	406	Case-control	Oculomotor Vestibular Reaction Time test battery	crHIT velocity gain crHIT absolute symmetry Predictive saccades Anti-saccades Optokinetic stimulation Horizontal smooth pursuit
Jafarzadeh et al.	2020	Iran	18-60 years	21	Prospective cross-sectional	Audiological testing Positional testing c-VEMP CDP DHI Oculomotor testing	c-VEMP Audiological testing
Parrington et al.	2022	USA	18-50 years	110	Cross-Sectional	VOMS NPC DHI Balance and gait assessments	VOMS DHI
Suleiman et al.	2015	Canada	41.8 +/- 10.5 39.8 +/- 16.2 years	20	Case-control	EVestG	EVestG

Table 1. Extracted data from selected studies

Ir Med J; May 2024; Vol 117; No. 4; P957
23rd May, 2024

The final nine studies included can be broken down into seven case control studies and two cross sectional studies.

Data was charted using a priori-piloted charting table by one reviewer, this was then reviewed by a second reviewer to ensure accuracy. The following information was charted; author, year, location, age, number of participants, exposure and control, type of study, assessments used, results. As per the recommended guidance on scoping reviews, no risk of bias appraisal was completed[9].

Figure 2: Geographical Location of included studies

Seven of the nine studies were conducted in the USA while one was conducted in Canada, and one in Iran. The age of the participants ranged from 18 to 65 years old. A total of 1,782 participants took part across all the studies included. USA had the largest number of study participants at 1,741. There were 1,202 male participants and 560 female participants. In one study, the gender of 20 participants included was unknown.

Ir Med J; May 2024; Vol 117; No. 4; P957
23rd May, 2024

Figure 3: Breakdown of participants by gender. 1,202 male participants, 560 female participants and 20 not specified.

In total 1,084 participants had mild traumatic brain injury and were age/sex matched against 698 controls. Of the participants with a diagnosis of mild traumatic brain injury, 255 were assessed within two weeks of their diagnosis. 659 of the mTBI participants had been diagnosed within six months of testing. 70 of the participants were assessed beyond six months of diagnosis. Both horizontal and vertical smooth pursuits showed potential in objectively measuring significant changes in the mTBI participants. Cochrane et al. found that with increased frequency came larger differences between concussed and healthy groups[10]. This study also found that results for horizontal smooth pursuit testing did not yield significant differences to aid in the diagnosis of concussion patients. Both Hoffer et al. and Balaban et al. found that horizontal smooth pursuit gain symmetry could be used to monitor recovery of concussed participants over time[11,12]. In one study, Cochrane et al. found that random horizontal and vertical saccade latencies showed fair to good reliability and individuals with concussion had significantly worse scores in comparison with healthy controls when assessed using random saccades. Cheever et al. found that initial results for saccadic testing between healthy controls and concussed individuals showed a significant difference and a regression model which included rapid horizontal eye saccades showed 90% accuracy when differentiating healthy individuals from healthy controls[13]. Optokinetic stimulation was examined and showed significant results in two studies. Cheever et al. found that those with prolonged symptoms of concussion improved over time on optokinetic testing scores and when used in a regression model along with smooth pursuits and gaze-stabilisation testing, 90% accuracy was achieved to discriminate between healthy and concussed participants. Hoffer et al. also found that optokinetic scores could be used to show recovery in concussed individuals over time. One study by Carrick et al. looked at posturography and head position testing as a method to identify concussion sufferers[14]. The modified clinical test of sensory interaction in balance (mCTSIB) was used along with four additional head position tests. This study found that head positional postures could be considered as biomarkers which can differentiate concussion patients from healthy controls. Another study by Suleiman et al. examined an emerging test called Electrovestibulography (EVestG) which objectively measures vestibular responses[15]. The results from this study suggest that there is a sensitivity of 85% and a specificity of 69% for diagnosis of side impact concussion when concussion patients were compared to healthy controls. Parrington et al. examines the Vestibular Ocular Motor Screening (VOMS) tool where its relationship to other measures such as self-reported vestibular symptoms, clinical measures of balance and gait, and higher-level motor ability tasks is evaluated[16]. In this study, the VOMS shows positive results for its relevance to the mTBI population and shows a strong correlation with other measures including the Dizziness Handicap Inventory (DHI) in capturing vestibular complaints among mTBI patients. In the study conducted by Cifu et al. computerised eye-tracking tests were conducted with a head-mounted eye-tracking device[17]. In this study, two tests showed positive results for possible objective methods to differentiate between the concussed and the healthy population. In the paper by Jafarzadeh et al. a relatively small sample size was used to assess vestibular deficits in patients with persistent symptoms of concussion[18]. In fourteen of the patients, cervical vestibular myogenic potentials (cVEMPs) were abnormal. This study had a small number of participants and no control group and therefore it was not as significant as other studies included in its ability to provide evidence of objective vestibular tests which can aid in the diagnosis of concussion.

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23rd May, 2024

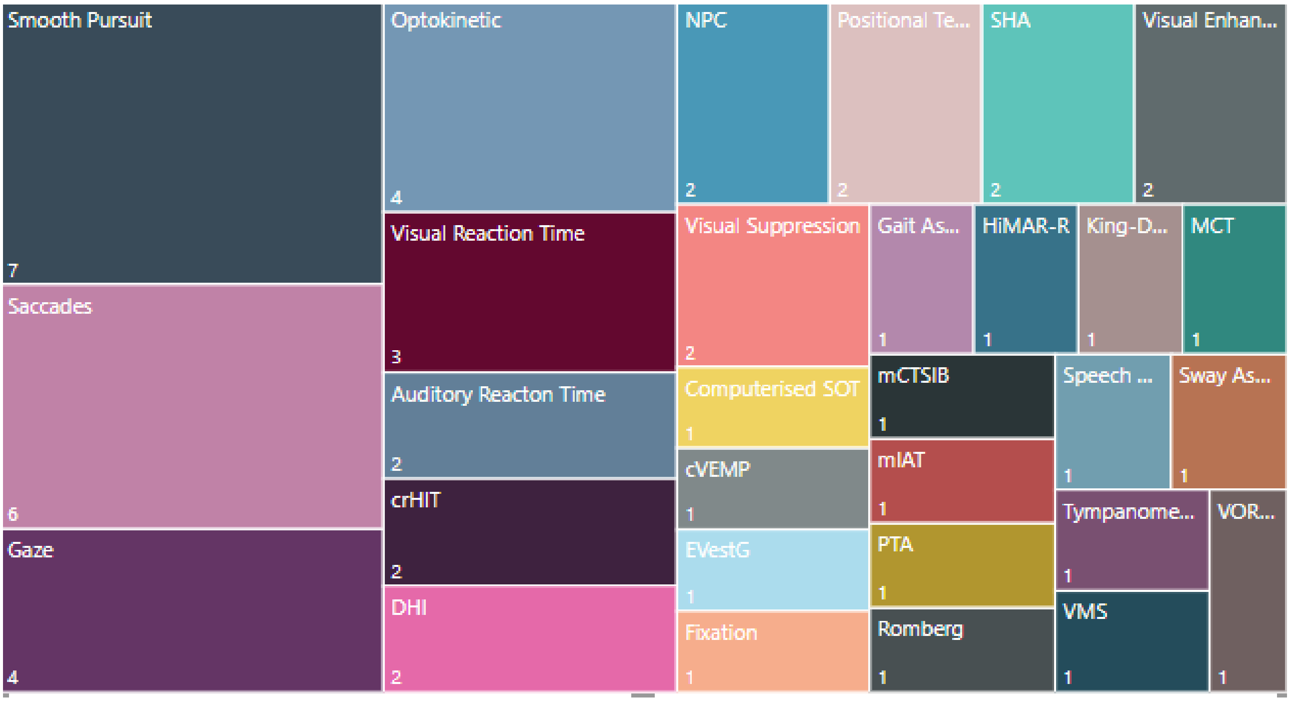

Figure 4: Audio/vestibular assessments identified within included evidence sources e.g., smooth Pursuit 7/9 studies.
Abbreviations: crHIT: computerised rotational head impulse test. DHI: dizziness handicap index. NPC: near point convergence. SOT: sensory organisation test. cVEMP: cervical vestibular myogenic potential. EVestG: electrovestibulography. mCTSIB: modified clinical test of sensory interaction in balance. mIAT: modified Illinois agility test HiMAR-R: revised high level mobility assessment tool. PTA: pure tone audiometry. King-Devick. Speech Testing. MCT: motor control test. VMS: visual motion sensitivity. SHA: Sinusoidal harmonic acceleration. Sway assessment. Tympanometry. VOR: vestibular ocular reflexes.

Discussion

mTBI is a difficult condition to diagnose and requires highly trained clinicians as well as a co-operative patient[19].Traditionally, vestibular assessment was not routinely included in the assessment for mTBI partly because vestibular clinics can be expensive to run[20.] In the studies included in this review, many of the assessment centres were fully equipped with a vestibular assessment lab, which allowed for a wide variety of highly specific tests to be conducted. However, we can also deduct that some of the more effective assessment tools within evidence sources did not require a full set of expensive equipment.
In all nine studies, vestibular testing methods showed a potential to play an important role in the diagnosis of concussion however studies showed high heterogeneity in modes of assessment. Therefore, it is challenging to meaningfully interpret the results. Moreover, the role and importance

of routine audio vestibular assessment for the diagnosis and management of concussion has not yet reached its full potential.
To this end, it is envisaged that this scoping review will guide future research in the area. According to evidence sourced in this review, audio vestibular assessment has potential to provide objective measures for successful diagnosis and monitoring mild traumatic brain injury. Thus, resulting in a possible decrease in the incidence of missed/wrong diagnosis and avoidance of complications associated with premature return to play or work.
Certainly, one of the aims of future research would be to compare different protocols of audio vestibular assessment to inform the development of an effective test battery for mTBI diagnosis. Many of the studies included are case control studies without randomisation hence future research is needed to ascertain the strength of evidence for inclusion of audio vestibular assessment in routine assessment for concussion. Furthermore, future research would benefit from an economic evaluation study comparing the cost and health outcomes of different technologies and assessments.

In conclusion, the role of audiology in the diagnosis of mTBI could improve the care and management of the condition as well as elevate the level of public awareness and its implication for the welfare of athletes, military personal and the general population. Audiology as a profession, could contribute greatly to the ongoing search for a solid and reliable diagnostic and management tool for concussion by using the existing knowledge on vestibular protocols to assess mTBI patients, and by delving further into its sensitivity and specificity in future research. The role of the audiologist may result in an important addition to the multi-disciplinary team tasked with clinical intervention for mTBI.

Declaration of Conflicts of Interest:
None declared.

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Data Accessibility Statement
Data associated with this scoping review is available to view in supplementary material. Any additional data will be made available upon reasonable request.

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