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Dizziness after traumatic brain injury: Overview and measurement in the clinical setting

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Abstract

Traumatic brain injury (TBI) may result in a variety of cognitive, behavioural and physical impairments. Dizziness has been reported in up to 80% of cases within the first few days after injury. The literature was reviewed to attempt to delineate prevalence of dizziness as a symptom, impairments causing dizziness, the functional limitations it causes and its measurement. The literature provides widely differing estimates of prevalence and vestibular system dysfunction appears to be the best reported of impairments contributing to this symptom. The variety of results is discussed and other possible causes for dizziness were reviewed. Functional difficulties caused by dizziness were not reported for this population in the literature and review of cognitive impairments suggests that existing measurement tools for dizziness may be problematic in this population. Research on the functional impact of dizziness in the TBI population and measurement of these symptoms appears to be warranted.

Keywords: *Brain injury, dizziness, vertigo, outcome assessment*

Introduction

According to a national consensus statement by the National Institute of Health (NIH) in the US, TBI is the leading cause of long-term disability among children and young adults [1]. The consequences of TBI are complex and far reaching. It is widely believed that many people with mild TBI do not seek medical advice and the prevalence is underestimated. Dizziness is a common complaint after TBI [2–6].

What is dizziness?

Dizziness is a very non-specific term [7]. It includes vague symptoms of disorientation and lightheadedness as well as the more clear-cut symptoms of vertigo (illusion of movement) and imbalance. This symptom can be placed into four broad categories [7]. These are:

(1) *Vertigo*: The illusion of movement. This is clearly related to the vestibular system.
(2) *Pre-syncopal lightheadedness*: A sensation of impending faint. This may be due to cerebral ischaemia, e.g. a drop in blood pressure related to postural change.
(3) *Multisensory dizziness*: Occurs with pathology involving multiple sensory systems. This diagnosis is said to be more common in older populations and in populations with systemic disorders (e.g. diabetes).
(4) *Psycho-physiologic dizziness*: Symptoms include visual vertigo and space phobia.

Dizziness can be further explained in relation to a definition of vestibular function as the 'neural sensory–motor interaction that leads to the

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Table I. Dizziness after TBI—prevalence and symptoms.

Reference and sample size	Severity of head trauma (*n*)	% reporting initial symptoms	% reporting symptoms at other time
[15], *n* = 25	Minor: LOC < 30 min (8) Intermediate: LOC 0.5–96 h (8) Major: LOC > 96 h (9)	48% (vertigo)	
[12], *n* = 176	Minor: all others (114) Moderate: GCS < 8 for 1–6 h (35) Severe: GCS < 8 for > 6 h (27)		5 years Minor: 32.5% (dizziness) Moderate: 37.1% (dizziness) Severe: 25.9% (dizziness)
[6], *n* = 84	MTBI: PTA < 24 h, no skull fractures, no previous ear disease or trauma (84)	23.8% (vertigo)	3 months: 3.6% (vertigo) 6 months: 1.2% (vertigo)
[2], *n* = 321	MTBI: PTA < 3 h, no skull fracture (129) Moderate: PTA 3 h to 7 days (192)	MTBI: 34% (vertigo) Moderate: 65% (vertigo)	5 years Minor: 20% (dizziness) Moderate: 47% (dizziness)
[16], *n* = 82	MTBI: LOC < 2 h (82)	78% (vertigo)	6 months 20% (vertigo)
[17], *n* = 38	'Minor head trauma': no operative definition (38)	81% (dizziness)	
[18], *n* = 256	No LOC (57) LOC < 1 h (66) LOC 1–24 h (39) LOC > 24 h (29) Duration unknown (65)	40.6% (vertigo)	23 years 7.5% (vertigo) 5.7% (a rocking feeling)
[13], *n* = 64	MTBI: PTA < 1 h (48) Moderate TBI: PTA 1–24 h (16)		3 months 29% (dizziness)
[14], *n* = 224	MTBI: GCS 13–15 on admission, LOC < 30 min, no focal neurological signs (224)		1 month: 43% (dizziness)
[19], *n* = 22	MTBI: unspecified (22)	41% (dizziness)	3 days: 0% symptomatic
[20], *n* = 1255	MTBI: GCS 13–15 (1255) NB large numbers lost to follow-up	2 weeks: 28% (dizziness)	6 weeks 9% (dizziness)

LOC = Loss of consciousness; GCS = Glasgow Coma Scale, scores level of coma on a scale of 3–15 (lower scores being more deeply comatose); MTBI = mild traumatic brain injury; PTA = Post-traumatic amnesia, measured using various scales (e.g. Westmead PTA scale, GOAT). Duration measured in days. Higher PTA = more severe injury.

maintenance of balance (motor function) and the perception of motion of objects relative to oneself (sensory function) as part of the larger and global function of orientation' ([8], p 595). It has been hypothesized that dizziness occurs when the multiple systems contributing to balance fail to function together. Patients experiencing dizziness have difficulties describing these sensations and dizziness of many descriptive types can be indicative of vestibular system disorders [8].

Dizziness has also been associated with whiplash-associated disorders (WAD) with symptoms described as 'disorientation and vague unsteadiness', exacerbated by neck movements and associated with neck pain. It is thought that these symptoms may relate to abnormal afferent input from the cervical proprioceptors [9].

Dizziness after TBI—how big is the problem?

Dizziness has long been recognized as a consequence of head trauma with articles describing this dating back to the early 1940s [10]. A review of the literature shows that dizziness is a symptom that is frequently investigated as an outcome following TBI [2, 6, 11–20]. However, there is little detail available regarding the subjective nature of these symptoms and their direct impact upon the survivor of TBI. Across studies reviewed, there is a lack of consistency regarding severity of TBI, the time at which symptoms are reported and a lack of detail regarding what is meant by dizziness (see Table I).

The widely differing estimates of the prevalence of dizziness after TBI can be ascribed to the inclusion/exclusion criteria, by the definition of dizziness, the way in which severity of injury is measured and also by the time post-injury at which the measurement was made.

Dizziness after TBI in children has also been reported, although by fewer authors [21, 22]. In a large series of children with TBI, 46% had immediate objective signs and 18% had signs persisting 2–8 years. Despite the high level of objective findings, subjective complaints of dizziness were rare [21]. Another author suggests that the difference between children and adults is due to the lack of psychosocial factors overlaying the injury and better central nervous system compensation [22]. Further comment regarding dizziness after TBI in paediatric populations is beyond the scope of this review.

Progression of symptoms of dizziness over time

Other authors have studied dizziness in TBI to determine natural history. A large cohort of Finnish ex-servicemen were studied 23 years post-injury [18]; 7.5% of the study participants experienced vertigo and 5.7% a 'rocking feeling' at the time of the study. There was no mention of any rehabilitation for their dizziness (other than pharmacological). In another study, patients after mild and moderate TBI were followed up for 5 years post-injury [2]. At 5 years, 20% of the 'minor' head injury group and 47% of the 'moderate' head injury group remained dizzy. There was no mention of concurrent rehabilitation, so it is not possible to say that this represents the true natural history of dizziness after TBI. However, at the time of publication of this study, rehabilitation for dizziness was not in common use.

Pathology

Vestibular system causes

TBI is thought to affect the vestibular system via direct damage to the vestibular end organs or vestibular nerve, disruption to brainstem pathways and disruption to visual, motor and ocular motor pathways via either primary or secondary injury [23].

Where vestibular system pathology is present after TBI, the following causes have been identified (Figure 1) [2, 24–29]. Widely differing reported prevalences of these pathologies (from a number of studies) was noted. These pathologies are:

(1) Benign paroxysmal positioning vertigo (BPPV). This occurs when otoconia (small calcium carbonate crystals attached to the otolith organs) become dislodged and move into the semi-circular canal(s).
(2) Central vestibular system problems (i.e. injury to the central nervous system sections of the vestibular system such as the vestibular nucleus via infarcts or haemorrhage).
(3) Other peripheral vestibular problems (e.g. loss or reduction of function in a semi-circular canal). While this damage may occur as a result of the injury, it may also occur as a side-effect of medications administered to treat the acutely unwell patient (e.g. aminoglycoside antibiotics—which are ototoxic [30]). Other less common causes of dizziness after TBI are perilymphatic fistula (PLF), post-traumatic Meniere's syndrome and direct damage to the vestibular nerve itself. PLF is characterized by the leakage of perilymph from the inner ear to the middle ear due to a membranous rupture [3]. Its prevalence is unknown. Onset of post-traumatic Meniere's syndrome is said to vary from immediately post-injury up to several years later—making causation difficult to prove. Symptoms include episodic vertigo, fluctuating hearing loss and tinnitus [4]. There are varying reports in the literature about direct damage to the vestibular nerve after trauma. One pathological study found damage in only one out of 12 cases of post-traumatic dizziness [31]. It was also noted that 50% of transverse petrous temporal bone fractures involve damage to the seventh and eighth cranial nerves [32].
(4) Finally, concomitant injuries should be considered (e.g. injuries to the visual system or injuries leading to significant restrictions of range of motion) and their likely effect upon the vestibular system's ability to effect its output [33].

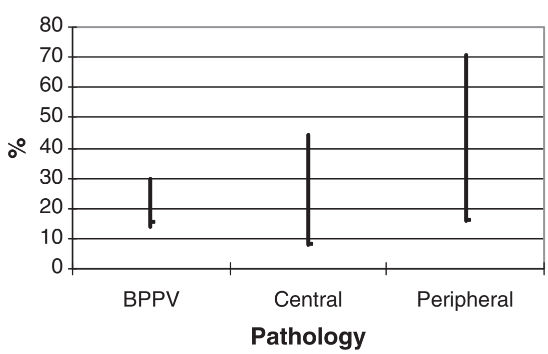

Figure 1. Range of reported frequencies of vestibular diagnoses.

Differences in the percentages of patients ascribed central compared to peripheral problems are likely due to subject selection, time from injury to assessment and the operational definitions for central as opposed to peripheral lesions.

In the most recent study dealing with pathology of dizziness after TBI [26], 26% had no demonstrable vestibular system abnormalities on testing. Earlier studies found even fewer objective signs [2]. It is perhaps in response to this lack of objective signs that the term 'inner ear concussion syndrome' or 'labyrinthine concussion' has been used [4, 34]. The pathophysiology of this syndrome is not clear [32]. Labyrinthine concussion has been defined as a 'descriptor for the spectrum of inner ear symptoms that may occur following many mild to severe head injuries' [34]. A more specific definition of the pathology is postulated to be 'microscopic haemorrhages in the cochlea and labyrinth' [32].

Possible non-vestibular causes

There is little information in the literature regarding non-vestibular causes of dizziness after TBI. Some patients may report 'dizziness' when changing body position with respect to gravity. They may be experiencing orthostatic hypotension. This may result from physical deconditioning, medullary injury or as a side effect of medications such as some anti-hypertensives, analgesics or beta blockers [35].

No literature was found reporting prevalence of orthostatic hypotension after TBI, but focal lesions of the brain may result in either hypo or hypertension [36].

Dizziness may also result from cervical injury [9]. The literature regarding the prevalence of cervical injury after TBI is sparse and tends to deal with fractures rather than WAD. Logically, in an incident causing TBI, one would expect the forces on the cervical spine to be sufficient to cause WAD and, thus, cervicogenic dizziness.

Post-traumatic seizures reportedly occur in between 1.9–30% of cases in the sub-acute phase [37]. Vestibular epilepsy is rare and is due to focal epileptic discharges in the temporal or parietal lobes [38]. One reported case of this was found in the literature [21].

Other causes of dizziness may be related to pre-existing conditions such as cardiac disease or diabetes. Many drugs may also lead to sensations of dizziness (e.g. benzodiazepines, anti-hypertensive agents, diuretics and anti-convulsants) [30]. Hyponatremia is also well recognized after TBI in both the acute and sub-acute settings [39–41] and hyponatremia has been noted to result in dizziness and orthostatic hypotension—amongst other symptoms [41–44]. These potential causes of dizziness need to be identified so that appropriate management can be commenced.

Subjective reporting of dizziness after TBI

To date, there is no published literature dealing specifically with the subjective experience of dizziness or its functional impact for this patient group.

Some descriptions for dizziness reported by patients with either mild TBI or WAD were attained as part of another study [45]. The authors noted that the complaints were very similar across the two groups. Specific descriptions included:

- Like being on a boat pitching in the water;
- Feels like he is falling backwards;
- Spinning spells;
- Unsteady in the dark; and
- Lightheaded—feels drunk all the time.

The functional impact of these complaints was not reported.

In another report, patients in rehabilitation with post-traumatic dizziness were studied [46]. Complaints of dizziness were listed as 'spinning or rotating sensation, balance problems (unstable when walking, staggering, veering to one side, falling) and symptoms of physiological arousal' ([46], pp 391–392). Further descriptions were not reported.

In a single case study, a client with a severe TBI was reported not to have spontaneously complained of dizziness or vertigo [47]. He was, however, observed to avoid certain movements and, when questioned specifically, he reported 'atypical dizziness with an occasional feeling of rotation' (p 633). A formal vestibular diagnosis was made.

It, therefore, remains unclear as to whether patients with dizziness after TBI have the same subjective complaints as persons with dizziness who have not suffered a TBI. This has significant implications for the use of questionnaires as outcome measures for dizziness after TBI. Additionally, there are no published reports dealing *specifically* with the experiences of those with moderate and severe TBI who suffer dizziness.

Difficulties experienced by people suffering dizziness

A range of difficulties noted by persons with dizziness in the general population has been reported. When the problems posed by dizziness are added to the difficulties known to be present in TBI, a logical argument can be formed about the likely additional impact of dizziness upon the person with TBI. Unfortunately, this aspect has not been studied in the TBI population to date. Problems noted in the general population are:

(1) *Balance difficulties*: Balance difficulties are well recognized in patients with dizziness without TBI (see Table II) [48–53]. Balance dysfunction after TBI is also common, even in those with no overt motor control difficulties or those with very mild TBI. Interestingly, these difficulties were noted despite exclusion of all patients with vestibular system problems and motor control difficulties [54, 55]. Balance deficits may be universal following TBI [56].

(2) *Falls*: Research regarding falls in younger patients is hampered by a lack of normative data. However, in a recent study it was found that six out of 34 patients under 65 years old with unilateral vestibular loss and 14 out of 20 with bilateral vestibular loss reported falling [57]. In another study, 36.8% of subjects with

dizziness and vertigo reported falling [58]. A search of the literature failed to find any articles dealing either with the prevalence of falls or specific risk factors for falls in the TBI population. It would seem reasonable to assume that persons with dizziness and TBI may have a higher risk of falling.

(3) *Functional limitations*: Vestibular disorders in the general population have been shown to have a significant impact upon the function of the individual. In a study on the functional impact of dizziness, it was found that patients with vertigo rated themselves as more impaired on functional tasks than they had been prior to developing vertigo [59]. Tasks nominated as difficult included getting out of bed, standing up from a chair, putting on shoes and socks, bathing, stair climbing, walking on uneven surfaces, shopping, driving and working. Logically, adding dizziness to the other consequences of TBI would likely result in further functional limitations.

(4) *Quality-of-life and psychological distress*: 70.7% of subjects in a study on the effects of dizziness nominated that dizziness had either a 'moderate', a 'great deal' or 'extreme impact' upon their quality-of-life [8]. In another study, a high degree of anxiety was found in a group of vertiginous patients [60]. People with TBI commonly suffer from symptoms of depression and anxiety [61, 62]. Quality-of-life is also affected after TBI and in a study of TBI survivors 10 years post-injury, 13% reported being very dissatisfied with their life in general [63]. It is not known if survivors of TBI who experience dizziness have a poorer quality-of-life or increased psychological distress than TBI survivors without dizziness.

Table II. Balance difficulties in vertigo sufferers and TBI survivors reported in the literature.

	Vertigo, no TBI	TBI, no vertigo
Sensory integration difficulties	√	√
Reduced amplitude of muscle activation in response to perturbation	√	
Increased antero-posterior sway	√	√
Increased lateral sway	√	
Altered perception of vertical	√	
Slowing of postural adjustments		√

How is dizziness measured?

Outcome measurement is becoming increasingly important today as therapists seek to justify their inputs to organizations paying for their service. Recently, in a review of outcome measures for dizziness and balance disorder patients, it was noted that 'there appears to be no adequate universal measure of outcome' ([64], p 519). Assessments are broadly: self report measures, measures of physical performance and combinations of the two. A summary of validity and reliability statistics reported is contained in Table III.

(1) *Assessments of physical functioning—observable physical performance*

As dizziness affects balance and performance of activities of daily living these can be observed and tested to attempt to quantify the functional impact of dizziness [49, 65]. This is the basis of many

Table III. Assessment tools.

Tool	Inter-rater reliability	Test–re-test reliability (non-TBI population)	Concurrent validity	Internal consistency
DGI [66]	$r = 0.95$–1.00*	$r = 0.8$*	nr	nr
CTSIB [69]	$R = 0.99$	$r = 0.99$	nr	nr
Gait measures [83, 84]	ICC = 0.999	nr	$r = 1.00$	nr
DHI [86]	nr	$r = 0.97$	nr	$r = 0.89$
DHI-S [91]	nr	$r = 0.95$	nr	nr
VHQ [93, 94]	nr	$r = 0.97$	nr	$\alpha = 0.93$
VSS [95]	nr	$r = 0.94$–0.95^a	nr	$r = 0.76$–0.88^a
VD-ADL [65]	nr	$r_c = 1.00^b$	nr	$\alpha = 0.97$
UCLA-DQ [98]	nr	nr	nr	$\alpha = 0.8236$
VDI [99]	nr	$r = 0.81$–0.87^a	nr	$\alpha = 0.92$
ABC [100]	nr	$r = 0.92$	nr	$\alpha = 0.96$
MSQ [103]	$r = 0.99$	$r = 0.96$ to 0.98^c	nr	nr

nr = not reported.
*trained observers.
[a]reported separately for each sub-scale; [b]assessed using concordance correlations; [c]reported separately for two different time intervals.

of the tests that are used clinically. All tests rely on patient effort.

Dynamic gait index. The Dynamic Gait Index (DGI) was designed to test higher level mobility skills [66]. It has eight items, scored by the therapist on a 0 (severe impairment) to 3 (normal) scale. It assesses skills such as the ability to turn, perform head movements while walking and climb stairs. While reliability is reported as excellent, a recent study showed that raters not trained by the authors had poorer reliability [67, 68]. This suggests caution when applying the DGI. The DGI is also related to self-reported fall history in those with dizziness [58]. There are no reports in the literature relating to the use of this scale in the TBI population and difficulties as noted above with reliability need to be considered by clinicians using this scale. However, in ambulant patients, this scale may prove useful.

The clinical test of sensory integration in balance. The Clinical Test of Sensory Integration in Balance (CTSIB) was first described in 1986 [69]. It is a timed test which aims to systematically test the influence of visual, proprioceptive and vestibular information on balance. It involves timed measures of balance under a variety of sensory situations and the influence of each of the sensory systems on balance is said to be able to be assessed. It has been shown to be a reliable test [70]. Recently, the relationship between the CTSIB and the computerised dynamic posturography sensory organisation test (CDP) was explored [71]. The CTSIB correlated with CDP, but was less sensitive. It could discriminate patients from normals. CDP itself has generated much debate in literature recently. Its use as a sole outcome measure has been questioned due to poor correlations with other measures. Generally, it is felt that CDP needs to be considered in conjunction with other measures [72–79]. Unfortunately, neither the CTSIB nor CDP have been correlated with functional measures, so it is unknown if improvements on the CTSIB or CDP correlate with functional improvements. The CTSIB is reported in the literature as a measure used in the TBI population [80, 81] and is simple to use in patients with independent standing. However, given uncertainty about its correlation with function, its use in isolation cannot be recommended.

Measures of gait—velocity and base of support. Measurements of gait velocity and parameters such as base of support and step length have also been used to document difficulties and improvements [71]. These are valuable to the clinician as they are easily administered and require no expensive equipment. A study of gait parameters in vestibulopathic patients demonstrated reduced velocity compared to normals, but not necessarily increased base of support [82]. Several authors have assessed the validity and reliability of timed walking and found it to be reliable and valid in the TBI population for both self-selected and fastest pace [83, 84]. Ecological validity (i.e. the patient's walking speed in real life situations compared to the clinic setting) has recently been shown to be poor in the TBI population [85]. The use of this measure is somewhat limited for evaluating dizziness after TBI as many other factors (such as motor control problems and orthopaedic injuries) may affect gait speed. However, given ease of assessment, this remains a popular outcome measure.

(2) *Self-report measures*

Dizziness as an experience is internal or private in nature and, as such, is not directly observable. Additionally, as dizziness is closely associated with psychological distress (and sometimes a psychiatric diagnosis), measurement of dizziness becomes complex.

Dizziness handicap inventory. Perhaps the most commonly reported outcome measure is the Dizziness Handicap Inventory (DHI) [86]. This was developed through case history reports of patients suffering dizziness. The DHI is a 25-item questionnaire, with questions answered with either a 'yes', 'no' or 'sometimes'. Questions pertain to physical, emotional and functional activities and these form sub-scales of the questionnaire. Questions all refer to 'your problem' rather than speaking about dizziness (e.g. 'Does looking up increase your problem?'). The DHI has been found to have minimal floor and ceiling effects and correlates with a computerized measure of gaze stability (dynamic visual acuity, DVA) [87, 88]. The DHI has been studied for correlations with physiological and balance measures, as well as other self-report measures (see Table IV) [65, 77–79, 89, 90]. The authors of the DHI have also reported a screening version of the DHI (DHI-S) [91]. The DHI-S contains 10 of the original questions and uses the original scoring system. The DHI has also been reported in a short form (DHIsf), constructed using Rasch analysis [92]. Interestingly, 20% of the sample of 55 patients failed to answer at least one question on the DHI due to complicated wording or dissatisfaction with the scoring alternatives. The DHIsf has 13 items and the scale only allows for a 'yes' or 'no' response. The reliability, unidimensionality and generalizability of the scale were supported

Table IV. Correlations between measures.

	CDP	DVA	ABC	VD-ADL	LM	DHI-S
CTSIB	$r = 0.41–0.89$ [71]					
DHI	$r < 0.49$ [77–79] $r = 0.5–0.6$ [90]	Statistically significant correlation, value not reported [88][a]	$r = -0.63$ [89]	$r = 0.66$ [65]	nc [79]	$r = 0.86$ [91]

LM = laboratory measures of vestibular function; nc = no correlation; [a]in TBI patients, correlation only present for the first week post-injury.

by the Rasch statistics—further details were not reported. No literature using this scale was found.

The DHI is probably the most commonly used self-report measure. However, as noted above, the wording of the scale is complex and assumes dizziness to be the primary symptom. This is likely not to be true in the TBI population. People with a TBI may find it very hard to separate out the relative contribution of dizziness to the difficulties they are experiencing. It may prove helpful for clinicians to assist the TBI patient to complete this scale to try to ensure it reflects dizziness and not other problems related to the TBI. The same difficulties apply to the DHI-S and DHIsf.

Vertigo handicap questionnaire. The Vertigo Handicap Questionnaire (VHQ) is a 26-item test measured on a 5-point ordinal scale (with the exception of the last question which has three parts scored as 'yes' or 'no') [93]. It was formulated from accounts of the vertigo and its psychosocial consequences obtained from an interview study [94]. It is unknown whether there were any participants who had a TBI. The items in the scale concern disruption and restriction of daily activities, but also assess psychological distress. This scale, like the DHI (and the VSS), assumes dizziness to be the primary problem and the same difficulties arise.

Vertigo symptom scale. The Vertigo Symptom Scale (VSS) assesses the nature and frequency of the complaints reported by people with dizziness (e.g. vertigo, autonomic symptoms and signs of anxiety) [95]. This was developed from the same interview study as the VHQ. There are 22 questions. The scale is comprised of two sub-scales—assessing symptoms of vertigo attacks and autonomic symptoms/anxiety. Concurrent and construct validity were demonstrated [95]. Anecdotally, in light of preliminary information emerging from a study in progress, the emphasis on autonomic symptoms in this scale may be less likely to reflect the symptoms experienced by the TBI population. Additionally, several items on the VSS pertain to symptoms such as headache, difficulties with memory and visual disturbance (these fall within the anxiety sub-scale). However, these items would clearly be endorsed by many people with a TBI—as a result of the effects of the TBI and not necessarily reflecting anxiety or the impact of dizziness.

Vestibular disorders activities of daily living scale. This scale (VD-ADL) was developed to measure self-perceived disablement in persons with vestibular disorders [65]. The scale has 28 items describing functional activities, scored on a 10-point ordinal scale rating independence. The subjects are asked to rate themselves after developing dizziness compared to before it was present. The group that this scale was tested on excluded patients with head trauma. This scale has not been reported in the TBI literature and it is not known if it reflects the experiences of TBI patients with dizziness. This scale has the same difficulties as the DHI, VSS and VHQ.

UCLA dizziness questionnaire. The UCLA Dizziness Questionnaire (UCLA-DQ) was developed as a quick office tool for neurotologists to use with their patients irrespective of diagnosis. The questionnaire has only five items, categorizing frequency, severity, impact on daily activities and quality-of-life and an item pertaining to fear of a dizzy episode. The authors contend that the tool is useful in assisting to identify those who will benefit from psychological assistance [8], but it does not appear that this scale was developed as an outcome measure. A review of the literature has shown only two articles using this tool as an outcome measure and its sensitivity to changes effected by therapy has been questioned [96–98].

VDI questionnaire. The VDI questionnaire (Vertigo, Dizziness and Imbalance) was developed using a combination of patient interview and peer-review methods [99]. The VDI has two sub-scales—one measuring symptoms and the other quality-of-life. There are 14 items in the symptoms scale and 22 in the quality-of-life scale. The questions are answered using a 6-point Likert Scale. No studies using this scale were identified from the literature review and attempts to obtain a copy of this scale for closer review have been unsuccessful.

The activities specific confidence scale. The Activities Specific Confidence Scale (ABC) was originally developed to assess balance confidence in higher functioning elderly adults and is not specific to those with dizziness [100]. The scale was developed using peer review and patient interview. The scale consists of 16 items representing functional activities and the respondent nominates their level of confidence in performing the activity on a 0–100% continuous scale. Changes on this scale may reflect a reduction in dizziness and improvement in balance in the TBI population, but this is yet to be demonstrated. The correlation with the DHI [89] (which is moderate) suggests that it may be useful in the dizzy population generally.

(3) *Combination measures*

Motion sensitivity quotient. As dizziness is often provoked by motion, an early way of quantifying this (and directing therapy) was to request the patient perform certain manoeuvres and then obtain a subjective measure of symptom intensity [101, 102]. The 'motion sensitivity quotient' (MSQ) consists of 16 movements which the patient performs in a set order [101]. Intensity of symptoms is scored on a 0 (none) to 5 (severe) scale and duration is scored on a 0–3 scale. The MSQ has recently been tested for validity and reliability and has been reported to be sensitive with a range of intensities and durations recorded [103]. Use of this scale in TBI has not been reported in the literature. However, it has the advantage of allowing the clinician to assess severity of symptoms immediately after a movement—and doesn't rely on memory function.

Summary of dizziness measures in TBI

There is little available evidence to support any of the above measures over another in the TBI population. None of the self-report measures have been validated specifically for use in the TBI population. The VSS, VHQ and MSQ have been used in reports of clinical trials of vestibular rehabilitation in TBI [46, 104]. Across review articles and texts on vestibular rehabilitation after TBI, there is no consistent recommendation of a particular measure [33, 80, 81, 105]. The choice of which of these measurement tools to use and when would appear to depend on the specific clinical presentation of the patient.

Measurement in TBI

The difficulties arising from TBI are well documented and are diverse [1, 106, 107]. Due to the diffuse nature of injuries, constellations of symptoms vary markedly between patients. The issues impacting upon the use of measurement tools primarily relate to cognitive problems. These difficulties have been documented in the older population suffering cognitive impairments [108]. The issues pertaining to TBI are dealt with below.

Cognitive difficulties

Self-awareness. Self-awareness has been studied extensively after TBI. One such study compared TBI clients' perceptions of their abilities in the active rehabilitation phase with the perceptions of rehabilitation staff, significant others (SOs) and against objective measures [109]. The correlation of scores between raters was low, with the poorest correlations between staff and clients [110]. The difficulties some clients experience in judging their own performance would potentially make the use of self-report scales for purposes of documenting improvements difficult. A later author noted this problem in a group of TBI survivors in the acute setting [111]. Again, clients rated themselves as being more able than staff did. Another rating done towards the end of rehabilitation showed significant improvements in scores given by staff, but only a very modest improvement was noted on the client's self-report. This has significant implications for use of scales for documenting improvements.

However, dizziness (like pain) is a perception and a study on reporting of pain showed TBI subjects actually reporting higher levels of pain than other raters. It seems reasonable to deduce that self-report scales might be a better at assessing severity of dizziness in the TBI client (i.e. severity rather than functional impact) [109].

In another study 2–5 years after injury, anxiety levels were measured. There was better concordance of self and SO reports; however, the SOs reported greater anxiety in the TBI client than the client did themselves [112]. Objective measures of anxiety did not support the SO reports. Thus, in chronic TBI, self-report measures may be at least as accurate as a proxy report—particularly when the report involves a measure of something less tangible. Anxiety is similar to dizziness in this respect and, indeed, there are many parallels between symptoms felt by patients suffering dizziness and those suffering anxiety [113]. The issue of proxies will be discussed further below.

Short-term (working) memory. Short-term memory reflects the ability of the TBI sufferer to retain recent information [106]. In order to accurately answer questions regarding the impact of dizziness on functional ability, a respondent must be able to recall the difficulties. Many scales demand recall of specific circumstances (e.g. the DHI asks if 'looking up' increases symptoms) and recall of the movement preceding the sensation of dizziness may exceed the memory capacity for the client. Additionally, several scales call for a judgement about how much or how often the problem affects them. Given difficulties with memory, this may not be valid—especially if difficulties with self-awareness co-exist with this. For this reason, an alternate strategy such as attaining immediate responses to movements (such as in the MSQ) may be preferable.

Cognitive flexibility and reasoning. Many scales will contain questions that are not relevant to each and every client. TBI clients may become 'stuck' (perseverative) on such a question and require assistance to move on. Equally, if a stated question (such as in the DHI: 'Because of your problem, do you restrict your travel for business or recreation?') is ambiguous (as any one of a number of possible reasons for restriction of travel can apply after TBI) or is difficult for the client to understand, cognitive difficulties may render the answer to a question non-reflective of the item the scale was designed to measure. For this reason, a scale for dizziness after TBI would need to be worded carefully to avoid such problems.

Attention. Difficulties with sustaining and directing attention to a task or shifting attention (or focus) from one task to the next may be evident after TBI [1]. If a TBI client has difficulties with maintaining attention, a lengthy questionnaire (such as the VHQ) may exceed their capabilities. For this reason, any scale to measure dizziness or its impact upon the TBI population would need to be brief.

Communicative difficulties

Communicative difficulties after TBI relate to cognitive impairments. Common problems include word-finding difficulties, poorly organized verbal output and inflexible understanding of language. Issues around speech and language suggest that a measurement tool will need to be easily understood, use concrete vocabulary and restrict replies to pre-set options (to reduce cognitive and word finding load).

Use of proxies

The use of proxies in the TBI literature is quite common—often due to cognitive issues. In this situation, a person close to the TBI client (a SO) is nominated to fill out a scale or questionnaire on behalf of the client (or a separate questionnaire is formulated for the SO). In a recent study, TBI patients and a SO were invited to complete an Awareness of Deficits Questionnaire [114]. No statistically significant difference between the reports was found although, 70% of the time, the SO nominated the difficulty to be more severe than the TBI client did. In another study (during active rehabilitation), self-report significantly underestimated level of impairment compared to staff ratings [111]. Other studies have included patients up to 5 years post-injury [115–118]. One author found that the SO rated the subject as more impaired on physical scales, the TBI subjects reported more 'internal' problems (fatigue and pain for example) and the SOs reported more psychosocial concerns [118]. This author concluded that, in order to obtain an accurate picture, it was wise to take use information from multiple sources. Other authors have found good correlation between TBI subjects and their proxy on items measuring concrete, observable behaviours [115–117]. These studies point towards those proxy questionnaires containing concrete and observable behaviours being more reliable and more in agreement with the subject's own perceptions.

With respect to TBI clients with dizziness, proxy information may be useful in determining the functional impact of dizziness. In clients with severe cognitive or communicative difficulties, proxy report may be the measure of choice. However, self-report regarding nature and severity of symptoms may be more accurate than proxy report where the client is able to communicate their perceptions.

Vestibular rehabilitation after TBI

In recent years, vestibular rehabilitation has emerged as an accepted and effective means of treating dizziness and vestibular disorders [119]. It involves exercises and activities designed to enhance central nervous system compensation to vestibular system dysfunction [120]. The increasing popularity of this mode of intervention has led to the need for outcome measures such as the ones described above.

Vestibular rehabilitation after TBI has been described in review articles based on personal experience [81, 121]. However, only two clinical trials of this intervention in the TBI population were found in the literature and one single case study [46, 47, 104]. While the results from one of the clinical trials were encouraging, it must be noted that the measurement scales utilised (VSS and VHQ) had not been validated for use in this population [46]. Therefore, the effectiveness of this intervention after TBI is yet to be properly established. There is a need for such a measurement tool.

Conclusions

While the prevalence of dizziness and the vestibular system difficulties that may cause this symptom are relatively well documented, other information about dizziness in this population is scant. The main issues pertain to functional impact of dizziness and measurement of dizziness after TBI. Given the complexities of measurement in this population, several measures used in conjunction would appear to be the most likely to give an accurate picture of the difficulties faced by TBI clients with dizziness. A combination of measures may be the best alternative. For example, the MSQ (once reliability in this population was demonstrated), some self or proxy report of functional impact and objective measures of balance and gait (which would provide observable clinical detail). The most problematic of these is the functional impact of dizziness, for the following reasons:

(1) The existing scales are rather complex and their wording may make them difficult to interpret in the light of other difficulties that may be present after a TBI.
(2) It is unknown whether the main reported difficulties due to dizziness in the general population are the same as in those with a TBI. If this proves to be different to other populations, the existing scales would lack validity in this population.

Further research is required into the functional effects and measurement of dizziness after a TBI.

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Appendix: Search strategy

A search of the electronic databases (Medline, Cinahl, Embase and PsycInfo) using the following search terms was undertaken: Brain Injury or Closed Head Injury or TBI or Mild TBI or Acquired Brain Injury and Vestibular Rehabilitation or Dizziness or Vertigo. Titles were screened manually for relevance to the topic and, in titles of interest, abstracts were also screened. The search was limited to the English language and all electronic databases were searched as far back as was possible. Reference lists from articles identified as relevant from the above strategies were manually searched for other articles of relevance.