



Review

Head first – Review of epilepsy head injury risk and protection

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ABSTRACT

Introduction: The causes of falls and resultant head injuries in people with epilepsy are complex and represent important clinical issues significantly impacting on safety, quality of life and long-term prognosis. A general solution for many years has been to provide helmets for head protection. There is poor understanding of the influencing risk factors and solutions to give person-centred clinical advice.

Methods: A focused narrative review was conducted to investigate the risk factors for seizure-related head injuries and evidence of current helmets to offer protection. Four databases were searched (Embase, Medline, PsycInfo and Cochrane Library) using combinations of text words and thesaurus terms for the retrieval of articles relating to seizure-related head injury. Articles for full analysis were selected by a ten item pre-defined inclusion criteria.

Results: Of 104 relevant studies longlisted 21 studies met four or more of the predefined criteria and included in this review. A further nine papers were included because they added additional relevant information.

Conclusions: Seizure-related head injury, although rare, may have serious consequences. High doses of anti-epileptic/antiseizure drugs (AEDs/ASDs) and a prescription for three or more AEDs/ASDs are significant, modifiable, risk factors for head injury. Differentiating confusion due to post-ictal changes or concussion can be challenging. Seizure-related cardiac causes leading to injury due to ictal bradycardia or asystole is under investigated. More research is required to validate the protective benefit of various helmet designs in seizure-related head injury. It is striking that there are no International Standards for protective helmets in seizures.

1. Introduction

The paper sets out to discover what the epidemiology is for head injury in epilepsy and how helmet design might address this. Falls and resultant head injuries in people with epilepsy are a complex clinical issue. Head injury is defined as ‘any trauma to the head other than superficial injuries to the face’ and concussion is defined as ‘a disturbance in the function of the brain caused by direct or indirect force to the head’ [1].

Concussion usually has a rapid onset and has a spontaneous resolution, but confusingly it includes many of the symptoms commonly associated with the post-ictal state such as headaches, co-ordination problems, cognitive and behavioural symptoms [2]. Current guidance offers advice on how to assess and manage head injuries but there is no mention of specific risk factors or the use of protective helmets [1].

Wearing a protective helmet is sometimes recommended to minimise the risk of head injury in seizures. However, the design of helmets for people with seizures in the UK has remained unchanged for years. They usually comprise a dense foam hat encased in leather and worn

with a chin strap. The foam can be built up dependent on whether the person usually falls forward or backwards. High impact foam isn’t breathable and people can become hot and uncomfortable, possibly in itself a trigger for seizures. To compensate for this, many helmets have ventilation holes which then have the downside of reducing protection from a penetrating injury. Extending the brim to protect the face can impede vision and risk increasing the likelihood of falls, (Personal communication, Nico De Wilde, Gelovations Europe, 2018) [3]. Although lacking hard evidence, the perceived opinion is that helmets are often viewed by people with epilepsy as unstylish, uncomfortable and stigmatizing; they may opt for wearing a sports or industrial cap instead, or decline to wear one altogether.

In order to provide person-centred clinical advice it is important to have an understanding of the risk factors for seizure-related head injuries and the evidence there is of current helmets offering protection against head injury and its complications.

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2. Method

This paper is an initial attempt to gather together the data on the relationship between seizures and head injury and a consideration of the role of protective helmets. Although a systematic review was considered the data was too disparate and limited for this thus the format of a focused narrative reviews was used. The ROBINS-1 tool (to examine for risk of bias in selected studies) was not used because the studies were either too varied in their approach or not detailed enough. We reported on data analysis where this was detailed in the paper, but there was wide variation in how this was done.

A focused narrative review using the PRISMA ScR checklist as a template was conducted. Two of the authors independently reviewed titles and abstracts. An iterative search, restricted to English language, was performed on the following databases: Medline, Embase, Cinahl, PsycInfo and Cochrane Database of Systematic Reviews using a combination of text words and controlled vocabulary (amended as appropriate for different databases). Headgear: "head protector", headgear, "head gear", "helmet*", "head protection", "protective head"; head injury: "head injur*", "brain injur*", "facial injur*", "maxillofacial injur*", "head trauma", "brain trauma", facial trauma, "maxillofacial trauma", "skull trauma", "skull injur*"; epilepsy: "epilepsy", "epileptic", "drop attack*", "seizure", "seizures"; cognition: "cognit*", "memory", "mental process*"; falls: "falls", "fall", "falling".

The Brain Injuries Trust, and two main manufacturers of head protection (Alto Form and Gelovations Europe), were contacted for details of any relevant studies. In addition, the Health and Safety Executive website was searched for relevant safety standards for protective helmets [4]. Following discussion with other health care professionals with relevant expertise, the following seven criteria were selected for this review:

- 1 Falls and head injury in seizure
- 2 Head protection in epilepsy
- 3 Cognitive outcomes post head injury following seizure
- 4 Type of seizure or epileptic syndrome
- 5 Confirmed diagnosis of epilepsy
- 6 Biomechanics of seizure-related falls
- 7 Comorbidities including ages, anti-epileptic medication, unsteady gait, Intellectual disability and cardiac causes

3. Results

Altogether 104 papers were assessed of which 21 studies met 4 or more of the above criteria and were included in this review (Table 1). A further nine papers were included because they added additional relevant information, even though they failed to meet the inclusion standard (Table 1). They are marked in the text with an asterisk. The criteria were used to consolidate the results into key areas of concern and interest.

3.1. Are head injuries in epilepsy an important concern?

A diagnosis of epilepsy should lead to a discussion of the risks involved and the activities to avoid or supervise and carefully manage. Falls and head injuries are risks that are commonly discussed, but how significant are they?

There were 343 Registrants on the Australian Epilepsy Research Register who participated in the two year 2010 Australian Epilepsy Longitudinal Survey. Data on self-reported seizure-related injuries was examined. Sixty-four percent of injuries were serious enough to require hospital treatment and 85% of the injuries involved soft tissue damage, of which 27% were facial injuries [5].

Similar findings were reported by Friedman in a two year follow up of 306 patients [6]. Fifty-four percent reported previous seizure related injuries at some time and 24% experienced recurrent injuries during the

study period. Head injury was noted to be the most frequent injury related to recurrent seizure. A further study from the same centre (n = 204) reported that a majority of injuries were mild and that head injuries did not impact on subsequent seizure presentation or frequency during the two year duration of the study [7].

The question of how serious head injuries are is dependent on definitions which, unfortunately, are rather unclear. A seven year prospective Swedish study examined the risk of injuries or accidents in 2343 people with epilepsy. Falls were the most frequent cause of injuries (n = 503) and traumatic head injury was found in 47 (2%) of the study group, but the severity of the trauma was not defined [8].

The cumulative effect of repeated head injury might cause more significant brain injury. This was investigated in a retrospective study of 5637 people with epilepsy or seizure disorder who had been admitted to the emergency department with traumatic brain injury. When compared with brain injured patients without epilepsy, the group with epilepsy was more likely to experience repeated head injury (OR = 1.54; 95% CI 1.41–1.69) and more severe brain trauma (OR = 1.49; 95% CI 1.38–1.60). It was considered that the long-term cumulative effect of repeated brain injury could lower the threshold for further seizures and possibly have an adverse effect on cognitive function. As a result of their findings researchers recommend protective head wear [9].

3.2. Maxillofacial trauma – is it a specific risk?

The desire to protect the person from seizure related head and facial injury is particularly strong because any facial trauma is visible and possibly disfiguring.

The increased risk of facial and oral injuries linked to seizures was identified in a prospective case controlled study (n = 159) evaluating oral and facial trauma caused by falls during seizures. The frequencies of oromaxillary trauma in the study and control groups were 23.9% and 4.4% respectively. Injuries to the face and teeth were statistically (p < 0.05) more common in people with epilepsy than in the general population. It was noted that individuals who suffer seizures without an aura (focal aware seizures) are the most affected [10].

3.3. Is seizure type a risk factor?

In view of the wide range of seizure types and the variation of the motor component, it is not surprising that some seizure types carry a greater risk of associated head injury. Several studies have examined whether particular seizure types hold higher risk for head injury and concluded that generalised tonic-clonic and atonic seizures are risk factors [5, 9, 10, and 11].

However, a different understanding of the risk factors for seizure-related injury has been suggested. A questionnaire based study of risk factors for seizure related injuries (N = 32) was conducted for people admitted to an epilepsy monitoring unit over a 5 month period. Statistical analysis of variables was done on age, epilepsy type, seizure frequency, history of generalized tonic-clonic activity and number of anti-epileptic drugs. It was found that the highest risk for seizure-related injury was the number of anti-epileptic drugs (AEDs) (also called antiseizure drugs - ASDs) that a person takes. People taking 0–1 AEDs were less likely to have injuries compared to those taking 2 or more AEDs/ASDs (37.5% vs 68.8%; p = 0.038). However, it is possible that polypharmacy may reflect the severity of the epilepsy rather than the adverse effects of AEDs/ASDs, although in this study seizure frequency and type did not determine the risk of injury [12].

Similar conclusions were reached in a three month observational study of 276 people with epilepsy which reported that generalised tonic clonic seizures and drug resistant epilepsy are high risk factors for seizure-related injuries [11]. It was noted that any loss of consciousness or any falls during an epileptic episode increased the risk of injury. In other studies, myoclonic and atonic seizures have also been identified

Table 1
Results of all selected studies.

Authors	Title	Journal	Date	Study type	Numbers	Aims of study	Limitations
Baca C.B.; Vickrey B.G.; Vassar S.D.; Cook A.; Berg A.T.	Injuries in adolescents with childhood-onset epilepsy compared with sibling controls	Journal of Pediatrics; Dec 2013; vol. 163 (no. 6); p. 1684	2013	Retrospective case-control lifetime injury assessments	501	To compare the occurrence of injuries in adolescents with childhood-onset epilepsy and matched sibling controls	Study examined all injuries not just head injuries
Bellon M.; Walker C.; Peterson C.	Seizure-related injuries and hospitalizations: Self-report data from the 2010 Australian Epilepsy Longitudinal Survey	Epilepsy and Behavior	2013	Data from the 2010 Australian Epilepsy Longitudinal Survey analysis	343	To examine self-report data on seizure-related injuries and hospitalizations	Self reported data difficult to confirm injury was directly related to a seizure-possible bias
Brown, Stephen	Deterioration	Epilepsia;	2006	Journal Article Review		A review of the features of cognitive decline in epilepsy citing head injury as a possible cause	
Camara-Lemarroy C.R.; Ortiz-Zacarias D.; Pena-Avendano J.J.; Estrada-Bellmann I.; Villarreal-Velazquez H.J.; Diaz-Torres M.A.	Alterations in balance and mobility in people with epilepsy	Epilepsy and Behavior	2017	Cross-sectional study of PWE and age- and sex-matched controls. Mobility and balance evaluated.		The purpose of this study was to evaluate mobility and balance in PWE.	Possible bias - Self-reported data.
Colnat-Coulbois, S.; Gauchard, G. C.; Maillard, L.; Vignal, J. P.; Vespiquani, H.; Auque, J.; Perrin, Ph. P.	Drug-resistant temporal lobe epilepsy is associated with postural control abnormalities	Epilepsy & Behavior	2011	Twenty-six patients with epilepsy and 26 age-matched healthy controls underwent a sensory organization test combining six conditions, with and without sensory conflicting situations	26 + 26	The aim of this study was to evaluate the characteristics of postural control in a homogeneous population of patients with complex partial TLE.	Sample size
De Groot M.H.; Van Campen J.P.C.M.; Tulner L.R.; Beijnen J.H.; Moek M.A.; Lamoth C.J.C.	The effects of fall-risk-increasing drugs on postural control: A literature review	Drugs and Aging	2013	Literature review Electronic databases, reference lists of identified papers were searched until June 2013. Only controlled research papers examining the effects of (falls risk increasing drugs frids on postural control were included. FRIDs were defined according to meta-analyses as antiepressants, neuroleptics, benzodiazepines, antiepileptic drugs, digoxin, type IA anti-arrhythmics, and diuretics		Meta-analyses found psychotropic drugs (antidepressants, neuroleptics, benzodiazepines, antiepileptic drugs) and some cardiac drugs (digoxin, type IA anti-arrhythmics, diuretics) are associated with increased fall risk. Balance and gait disorders are the most consistent predictors of future falls.	Literature review
Friedman D, Chiang S, Tobias R	Do recurrent seizure-related head injuries affect seizures in people with epilepsy?	Epilepsy & Behavior	2012	This study systematically assessed for any possible effects of SEIZURE RELATED HEAD INJURY on seizure frequency and seizure semiology over a 2-year period.	204	To examine the effect of SRHI on the progression of seizure frequency over time, seizure frequencies at 6-month intervals over a 2-year study period were obtained	Short 2-year time frame, ? too short a period to adequately address the potential exacerbating properties of SRHI on epilepsy. Did not specifically assess antiepileptic drug changes in medications which may have led to differences in seizure frequency, thus leading one group to be subjected to more head injuries. Small sample size. 2-year time frame? Too short a period. Direct questioning during routine clinical review- may be influenced by questioners style and bias
Friedman D, ⁸⁶ Tobias R, Akman C, O'Brian Smith E, Levin H	Recurrent seizure-related injuries in people with epilepsy at a tertiary epilepsy A 2-year longitudinal study	Epilepsy & Behavior	2010	Investigation into SRIs and their associated risks in PWE in PWE with direct and systematic inquiries during routine clinic follow-up visits over a 2-year period attending a tertiary care centre.	306		

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Table 1 (continued)

Authors	Title	Journal	Date	Study type	Numbers	Aims of study	Limitations
Hill K.; Petty S.; O'Brien T.; Habib N.; Paton L.; Berkovic S.; Shiek Ahmad B.; Kantor S.; John W.; Lawrence K.	Balance impairment an unrecognised contributor to fall and fracture risk in anti-epileptic medication users: Survey findings and a twin-sibling study	Physiotherapy	2011	A detailed survey of falls, fractures and associated risks.	150 people	The purpose of this study was to determine the effect of AED/ASDs on balance, falls and fractures.	Sample size
Hsieh, Kelly; Rimmer, James; Heller, Tamar	Prevalence of falls and risk factors in adults with intellectual disability	American journal on intellectual and developmental disabilities;	2012	Research Support	1.515	Purpose of this study - to examine the prevalence of falls and risk factors for falls in adults with intellectual disability using data from the Longitudinal Health and Intellectual Disability Study	Study limited to data extracted from longitudinal health LD study.
Lees, Andrea	Retrospective study of seizure-related injuries in older people: A 10-year observation	Epilepsy & Behavior	2010	Patients aged 65 years or older having injuries secondary to seizures between July 1, 1999, and June 30, 2009, were identified through a diagnostic coding system	615 patient episodes of seizures were recorded.	Aims of this study :to assess the characteristics and risk factors for injuries caused by seizures in older persons	Retrospective study using a diagnostic coding system
Mahler B.; Tomson T.; Carlsson S.; Andersson T	Injuries and accidents in epilepsy: A prospective, population-based cohort study on incident cases	Epilepsia		Patients and controls were followed until December 31st, 2014 in the Swedish Outpatient Register, the Swedish Hospital Discharge Register and the Cause of Death Register for information on accidents and injuries based on ICD codes	18.672	: To study the risk of injuries or accidents for people with epilepsy (PWE). Over a 7 year period	Study not specific to head injury All injuries investigated but TBI highlighted
Maideniuc C.; Stino A.; Basha M.	Predictive risk factors of seizure-related injury and postictal behavioral changes	Epilepsy Currents	2015	Questionnaire enquiring about the types of injuries suffered due to seizures and agitation and aggressive behaviour occurring after seizures	32	Aim to identify epilepsy patients risk for seizure-related injury (SRI) and postictal behavioural changes	Study size. Limitations with self reported/carer reported questionnaires
Onder O.; Bilgin R.R.; Kahyaolu N.; Donmez Balci B	Evaluation of balance and gait abnormalities in refractory epilepsy: Comparison with remission epilepsy	Epilepsia	2036	People with epilepsy were classified in two groups: Treatment-resistant epilepsy and remission epilepsy. All patients were applied Tinetti Balance and Gait Scale and Falls Efficacy Scale. Also completed the Modified Clinical Test of Sensory Interaction on Balance, Walk Across, Tandem Walk, Step/ Quick Turn, Limits of Stability tests in Balance Master systems	104	Aim of this study : To evaluate abnormalities of balance and gait and to estimate the risk of falling in people with epilepsy.	Study size
Pariente, Antoine; Dartigues, Jean-Francois; Benichou, Jacques; Letenneur, Luc; Moore, Nicholas; Fourrier-Réglat, Annie	Benzodiazepines and injurious falls in community dwelling elders.	Drugs and Aging	2008	A nested case-control study with 10 year follow up		OBJECTIVE To estimate the impact of benzodiazepine-associated injurious falls in a population of elderly persons Outcome measure used was the occurrence of an injurious fall	Controls frequency-matched to cases but not always. Difficult age to study due to multimorbidity
Petty S.J.; Haber N.E.; Paton L.M.; O'Brien T.J.; Wark J.D.; Hill K.D.; Lawrence K.M.; Berkovic S.F.; Seibel M.J	Balance impairment in chronic antiepileptic drug users: A twin and sibling study	Epilepsia	2010	AED/ASD-discordant, twin and sibling matched-pair approach was adopted, and assessed clinically relevant subgroups: AED/ASD polytherapy; longer-duration AED/ASD; and falls history	29	This study investigated chronic AED/ASD use and physical contributors to falls risk	sample size

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Table 1 (continued)

Authors	Title	Journal	Date	Study type	Numbers	Aims of study	Limitations
Strzelczyk, Adam; Bauer, Sebastian; Knake, Susanne; Oertel, Wolfgang H; Hamer, Hajo M; Rosenow, Felix	Ictal asystole in temporal lobe epilepsy before and after pacemaker implantation.	Epileptic disorders: international epilepsy journal with video tape	2008		1	A single case study - A 41-year-old man who presented with refractory partial seizures resulting in syncope leading to severe head trauma, as the only ictal semiology	Single case study
Strzelczyk, Adam; Cenus, Margarethe; Bauer, Sebastian; Hamer, Hajo M; Mothersill, Ian W; Grunwald, Thomas; Hillenbrand, Barbara; Ebner, Alois; Steinhoff, Bernhard J; Krämer, Günter; Rosenow, Felix	Management and long-term outcome in patients presenting with ictal asystole or bradycardia.	Epilepsia;	2011	PURPOSE to examine ictal asystole (IA) and ictal bradycardia (IB) as a rare autonomic symptoms during epileptic seizures and may be potentially life-threatening.	16	A multi-centre study to evaluate the management and long-term outcome in patients with IA and IB. All patients with IA and IB were included from four epilepsy centres from 2002 until 2009. A standardized assessment form was used, clinical data, treatment decisions, and outcomes were extracted from patient charts and simultaneous electroencephalography/electrocardiography recordings.	sample size
Thompson P, Duncan J	Cognitive Decline in Severe Intractable Epilepsy	Epilepsia		To explore the relation between seizure related variables and cognitive change in patients with severe intractable epilepsy	136	Retrospective analysis of data from 136 patients who had undergone a cognitive assessment on two occasions at an interval of ≥ 10 years. Cognitive measures included tests of memory and executive skills in addition to intelligence quotients. Purpose - to determine the association of AED/ASD use with falls and fractures in an ambulatory clinical population	Sample size.
Wark J.D.; Shiek Ahmad B.; Petty S.; O'Brien T.; Hill K.	Balance impairment is an unrecognized contributor to fall and fracture risk in anti-epileptic medication users	Bone	40664	In a detailed balance assessment conducted in AED /ASD exposure-disorder twin and sibling pairs	150	Purpose - to determine the association of AED/ASD use with falls and fractures in an ambulatory clinical population	sample size
Wilson D.A.; Selassie A.W.	Acute traumatic brain injury in persons with epilepsy and seizure disorders			A retrospective cohort study of all TBI encounters in South Carolina non-federal emergency departments and hospitals between 1998 - 2011.		To examine if people with pre-existing seizure disorder are more likely to sustain repetitive TBI and higher severity than those without.	
*Deekollu D.; Besag F.M.C.; Aylett S.E.	Seizure-related injuries in a group of young people with epilepsy wearing protective helmets: Incidence, types and circumstances	Seizure; Jul 2005; vol. 14 (no. 5); p. 347-353	2005		33	To provide information on the incidence, types and circumstances of injuries sustained in a group of young people with epilepsy using protective helmets	sample size
*Hartwig E.C.; Wenzel F.J.; Hintz C.S.	Maxillofacial protective headgear	Orthotics and Prosthetics; 1977	1977	Single case study	1	Adaptation of a protective helmet to protect maxillofacial area Single case study	age of study. Materials and design would have changed over the years. No comment on tolerance or affect on quality of life. Focus only on preventing injuries Single case study
*Martin B	Traumatic intrusion of maxillary permanent incisors into the nasal cavity associated with a seizure disorder: Report of a case'	Dental Traumatology	2003	Single case study			review article
*Mott T, McConnon M, Rieger B	Subacute to Chronic Mild Traumatic Brain Injury	American Family Physician	2012	A review article			
*Nonato, Eduardo Ruocco; Borges, Moacir Alves	Oral and maxillofacial trauma in patients with epilepsy: Prospective study based on an outpatient population	Arquivos de Neuro-Psiquiatria	40695	A prospective case-control study	159+68 control	This study aimed to evaluate oral and maxillofacial trauma caused by falls during epileptic seizures	all facial injuries

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Table 1 (continued)

Authors	Title	Journal	Date	Study type	Numbers	Aims of study	Limitations
*Torjesen Ingrid	Traumatic brain injury raises dementia risk, large study suggests	British Medical Journal	2018				
*Shankar R, Rowe C, Van Hoom A, Henley W, Laugharne R, Cox D, Pande R, Roy A, Sander J	'Under representation of people with epilepsy and intellectual disability in research'	PLoS One	2018				
*Strzelczyk A.; Hermesen A.; Belke M.; Oertel W.H.; Knake S.; Rosenow F.; Hamer H.M.	Incidence, hospitalization costs and risk factors of epilepsy-related injuries and accidents	Epilepsia	2014	three months observation period. Data on socioeconomic status, course of epilepsy as well as quality of life measurements were recorded using validated patient questionnaires	276 outpatients	Objective of this study was to provide incidence estimates, determine hospitalization costs and define risk factors for epilepsy related injuries and accidents	
*Shiek Ahmad B.; Wark J.D.; O'Brien T.J.; Hill K.D	Fractures and falls with chronic antiepileptic drug use and patient awareness of the issue	: Osteoporosis International	20787	Cross sectional survey conducted in epilepsy clinic outpatients and a nonepileptic comparison sample	150 AED/ASD-users 506 healthy comparison subjects	To evaluate the prevalence of fractures and falls in epilepsy patients taking antiepileptic drugs (AED/ASD) and assess level of awareness about AED/ASD-related bone health and fracture risk.	
<p>Authors</p> <p>Conclusions</p> <p>Inclusion Criteria</p> <p>Falls and co morbidities for falls – if present (P)</p>							
Baca C.B.; Vickrey B.G.; Vassar S.D.; Cook A.; Berg A.T.	With the exception of head injuries, we found no evidence of an increased risk of injury in a representative cohort of children with epilepsy compared with matched sibling controls		P	Head Injury			
Bellon M.; Walker C.; Peterson C.	Respondents with seizure-related injuries had significantly earlier seizure onset, with risk of injury related to myoclonic and atonic seizures and currently taking 3 or more AEDs/ASDs. Soft tissue injuries were the most frequently reported (85%), with 27% indicating facial injuries. The high rate of hospitalizations largely for soft tissue injuries suggests that access to more appropriate care was not available.		P	Head Injury			
Brown, Stephen	Concludes that head injury may be implicated in cognitive decline in people with epilepsy.		P	Epilepsy/seizure type			
Camara-Lemarroy C.R.; Ortiz-Zacarias D.; Pena-Avendano J.J.; Estrada-Bellmann I.; Villarreal-Velazquez H.J.; Diaz-Torres M.A.	Conclusions People with epilepsy (PWE) are burdened by physical disability and side effects of antiepileptic drugs (AED/ASD). These factors place them at risk for reduced mobility and falls. PWE have significant alterations in balance and mobility, independently of AED/ASD use or seizure control.		P	Head protection			
Colnat-Coulbois, S.; Gauchard, G. C.; Maillard, L.; Vignal, J. P.; Vespignani, H.; Auque, J.; Perrin, Ph. P.	PWE displayed poorer postural control. Potential antiepileptic drug side effects, vestibular dysfunction possibly related to temporal pathology		P	Head protection			

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Table 1 (continued)

Authors	Conclusions	Inclusion Criteria																				
		Falls	Head Injury	Epilepsy/seizure type	Head protection	AEDS/ASDs	Age	Intellectual Disability	Gait instability	Cardiac	cognitive outcomes											
De Groot M.H.; Van Campen J.P.C.M.; Tulner L.R.; Beijnen J.H.; Moek M.A.; Lamoth C.J.C.	Psychotropic drugs cause impairments in postural control. Sedative effects of these drugs on postural control are reversible, as was proven in intervention studies where FRIDs were withdrawn. The findings of the present literature review highlight the importance of using psychotropic drugs in the older population only at the lowest effective dose and for a limited period	P				P																
Friedman D, Chiang S, Tobias R	SRHI occurred in 18.1% of the cohort. Most injuries(91%) were classified as mild. Though seizure frequency varied following head injury, overall seizure frequency was not significantly impacted by presence or absence of SRHI over the 2-year study period.Changes in seizure semiology were not observed in those with SRHIs. Although mild SRHI is common among PWE, it does not appear to have an effect on seizure characteristics over a relatively short period	P	P	P																	P	
Friedman D, ⁸⁸ Tobias R, Akman C, O'Brian Smith E, Levin H	Past seizure related injuries occurred in 54% of all patients.24% experienced recurrent SRIs.Past SRI was associated with tonic-clonic seizures and cognitive impairment. recurrent SRI was associated with TCSsThe most recurrent SRIs (72%) involved head injury. TCSs represent a risk factor for recurrent SRIs.	P		P		P																P
Hill K.; Petty S.; O'Brien T.; Habib N.; Paton L.; Berkovic S.; Shiek Ahmad B.; Kantor S.; John W.; Lawrence K.	35% female, 50% male AED/ASD-users reported life-time history of fractures compared to 32% of the control group. In AED-users, fracture risk increased with age, longer therapy duration and poly-therapy. Prevalence of falls and multiple falls in the preceding year were significantly higher in female AED/ASD-users than the comparison sample. There was increased problems of balance impairment, falls and fractures for people taking AEDs/ASDs, especially people on poly-therapy, a longer therapy duration or those with recent falls, had poorer balance performance.	P		P		P																P
Hsieh, Kelly; Rimmer, James; Heller, Tamar	The risk factors for falls in adults with intellectual disability are -female, having arthritis, having a seizure disorder, taking more than 4 medications, use of walking aids, difficulty lifting/carrying greater than 10 lb.	P	P	P		P																P

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Table 1 (continued)

Authors	Conclusions	Inclusion Criteria									
		Falls	Head Injury	Epilepsy/seizure type	Head protection	AEDs/ASDs	Age	Intellectual Disability	Gait instability	Cardiac	cognitive outcomes
Lees, Andrea	Findings suggest that falls rather than seizures are the dominant influence in the pathogenesis of fractures in older People with epilepsy. Findings 53% of seizures occurred indoors, and the majority were generalized tonic-clonic seizures. Of the seizure-related injury events, 42% were single injuries, and 61% were multiple injuries. Predominant injuries were soft tissue injuries 55%, fractures 35%, and head injuries 10%. Most frequent injuries among exposed were those to the upper and lower extremity, followed by traumatic brain injury. Most frequent causes were falls, exposure to external forces or traffic accidents. Risks remained elevated after adjusting for comorbidities and accidents occurred more frequently during the first year after seizure onset. Conclusion: There is an increased risk for injuries and accidents among PWE, especially early after diagnosis and among older patients.	P	P	P	P	P					
Mahler B.; Tomson T.; Carlsson S.; Andersson T		P	P	P		P					
Maideniuc C.; Stino A.; Basha M.	The number of AEDs/ASDs epilepsy patients takes correlates with an increased SRI and PIB. This may indicate seizure severity or may be due to the side effects of AEDs/ASDs. The number of seizures, seizure type, and epileptic versus non-epileptic aetiologies were not risk factors for seizure related injury and Post Ictal Behaviour change	P	P	P		P					
Onder O.; Bilgin R.R.; Kahyaodlu N.; Donmez Balci B	Conclusion the abnormalities of balance and gait are related not only to the frequency and total number of the seizures, but also to diversity of the seizure types, duration of the treatment, number of AEDs/ASDs, age at onset of the disease and existence of some cognitive dysfunction. Remarkable abnormal findings were noted in the remission epilepsy group. It was concluded that factors other than frequency and total number of seizures must be operative in balance and gait abnormalities.	P		P		P				P	
Pariente, Antoine; Dartigues, Jean-Francois; Bentchou, Jacques; Letenneur, Luc; Moore, Nicholas; Fourrier-Régat, Annie	RESULTS Benzodiazepine use was significantly associated with the occurrence of injurious falls. Also noted a significant interaction with age. The adjusted odds ratio for injurious falls in subjects exposed to benzodiazepines was 2.2 (in subjects aged > or = 80 years and 1.3 in subjects aged or = 80 years. The incidence of injurious falls in subjects aged > or = 80 years exposed to benzodiazepines in the PAQUID cohort was 2.8/100 person-years. Over 9% of these falls were fatal.	P		P		P				P	

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Table 1 (continued)

Authors	Conclusions	Inclusion Criteria									
		Falls	Head Injury	Epilepsy/seizure type	Head protection	AEDS/ASDs	Age	Intellectual Disability	Gait instability	Cardiac	cognitive outcomes
Petty S.J.; Haber N.E.; Paton L.M.; O'Brien T.J.; Wark J.D.; Hill K.D.; Lawrence K.M.; Berkovic S.F.; Seibel M.J	Results - Balance performance is impaired in AED/ASDs users compared to their matched nonuser siblings. Pairs where the AED/ASD users took AED/ASD poly-therapy, or had a longer duration of AED/ASD use, had more impaired balance performance. In this population balance deficits may contribute to the increased rate of fractures. A cause of falls may be ictal asystole or ictal bradycardia	P	P	P	P	P		P			
Strzelczyk, Adam; Bauer, Sebastian; Knaake, Susanne; Oertel, Wolfgang H; Hamer, Hajo M; Rosenow, Felix	Drug-resistant patients not suitable for epilepsy surgery, implantation of a cardiac pacemaker may prevent sudden falls as well as trauma. Guidelines for the care of these patients are missing. Based on results and previously reported cases an algorithm was proposed.	P	P	P		P			P		
Wark J.D.; Shiek Ahmad B.; Petty S.; O'Brien T.; Hill K	Cognitive decline was severe and occurred across a wide range of cognitive functions. The strongest predictor of decline was frequency of generalized tonic-clonic seizures. Complex partial seizure frequency was associated with a decline in memory and executive skills but not in IQ. Seizure related head injuries and advancing age carried a poor cognitive prognosis. Periods of remission were associated with a better cognitive outcomes. Results highlight the problems of balance impairment, falls and fractures for people taking AEDs, especially those on poly-therapy, having longer therapy duration or with recent falls. Strategies are required to manage balance impairment, falls and fracture risk for patients taking AEDs/ASDs. Understanding the contribution of balance impairment to falls and fractures opens opportunities for exercise-related interventions in addition to reducing bone fragility in this group who usually require long term medication use.	P	P	P		P		P		P	
Wilson D.A.; Selassie A.W.	A major concern, especially in persons with epilepsy with poorly controlled seizures, is the cumulative effect of repetitive Traumatic brain injury within a short period of time resulting in insufficient recovery time between TBIs. The findings underscore the risk of sustaining severe and repetitive TBI in persons with an epileptic seizure disorder. Adequate control of seizures and use of protective equipment in those with intractable and atonic seizures and a propensity for falls are crucial to avoiding TBI.	P	P	P	P					P	

(continued on next page)

Table 1 (continued)

Authors	Conclusions	Inclusion Criteria									
		Falls	Head Injury	Epilepsy/seizure type	Head protection	AEDS/ASDs	Age	Intellectual Disability	Gait instability	Cardiac	cognitive outcomes
		Falls and co morbidities for falls – if present (P)									
*Deekollu D.; Besag F.M.C.; Aylett S.E.	Injuries continue to occur despite the use of helmets. Changes to the helmet design and modifications to suit the seizure type may improve the protection offered by helmets.	P	P	P	P						
*Hartwig E.C.; Wenzel F.J.; Hintz C.S.	At time of report there seizures had continued but no further injuries and Pt seemed to be tolerating the helmet. Comment in article of the difficulties in materials and design	P	P	P	P						
*Martin B	Results - Complete intrusion injuries in the mixed or permanent dentition are relatively rare. A case history of an adolescent male who sustained displacement of a lateral incisor into the nasal cavity and complete bony intrusion of the three other permanent maxillary incisors because of a fall following a seizure. Counselling on helmet/face-shield usage for seizure-susceptible patients must be provided and documented, particularly after sustaining traumatic injury	P	P	P	P						
*Mott T, McConnon M, Rieger B	A review article that discusses presentation, lack of a universally accepted definition of TBI, treatment of persistent physical symptoms and red flags	P									P
*Nonato, Eduardo Ruocco; Borges, Moacir Alves	Generalized tonic-clonic, generalized and non-classified seizures were strongly associated with trauma. : Injuries to the face and teeth are statistically more common in patients with epilepsy than in the general population, and that individuals who suffer seizures without aura are the most affected.	P	P	P	P						
*Torjesen Ingrid	A nationwide population cohort study suggests people who have sustained a traumatic brain injury have a higher risk of developing dementia and Alzheimer's disease.	P									P
*Shankar R, Rowe C, Van Hoorn A, Henley W, Laugharne R, Cox D, Pande R, Roy A, Sander J	Epilepsy is common in people with intellectual disability. Both conditions are associated with higher levels of morbidity, stigma and premature mortality.										P
*Strzelczyk A.; Hermesen A.; Belke M.; Oertel W.H.; Knake S.; Rosenow F.; Hamer H.M.	In the hospital cohort nine of the 96 inpatients (9.3%) presented with seizure-related fractures and other lacerations requiring admission. Seven patients presented with fractures of the skull, vertebra, maxilla, mandible, zygomatic bone and limbs; two patients had lacerations requiring hospital admission	P	P	P	P						
*Shiek Ahmad B.; Wark J.D.; O'Brien T.J.; Hill K.D	morbidity, stigma and premature mortality	P									P

Table 2
Risk Factors for Seizure Related Head Injury.

Risk factors	Key factors and suggested actions	Evidence
Tonic clonic and generalised seizures	Injuries to teeth and face 6x more common than in general population. Review medication. Learn to respond to any aura.	Strzelczyk et al, Friedman et al, Nonato et al, Thompson and Duncan Brown
Atonic or myoclonic seizures	Unexpected, sudden loss of muscle tone. Review medication. Identify high risk situations	Bellon et al, Wilson and Selassie
Drug resistant epilepsy	May be linked with more severe brain dysfunction and share a common pathology. Consider other interventions such as VNS, brain surgery	De Groot et al, Shiek Ahmad et al,
Poly-pharmacy	Avoid 3 or more AEDs/ASDs. Consider effect of concomitant medication	Wark et al, Hill et al,
Intellectual disability	Linked with a range of co-morbidities that increase risk of falls and head injury	Shankar et al, Friedman et al, Hsieh et al,
Early onset of seizures	Especially in first year after onset	Mahler et al,
Lack of an aura	Linked to maxillo-facial injury. May be possible to teach recognition of pre-seizure state	Nonato et al,
Poor postural control	Temporal lobe seizures linked with vestibular dysfunction. AEDs/ASDs can affect postural balance. Consider postural exercises. Older age	Colnat-Coulbois, Camara-Lemarrroy et al,
Ictal associated abnormal cardiac arrhythmia	Bradycardia or asystole. Consider pacemaker	Strzelczyk et al 2008 Strzelczyk et al 2011
Not wearing a protective helmet	The benefit of a helmet is unknown, but may help in individual cases	Hartwig et al, Wilson and Selassie,
Age, gender,	Adolescence, older age, female	Thompson and Duncan, Shiek Ahmad et al, Bacca et al, Lees.

as risk factors [5,9] See Table 2.

3.4. Is gait instability and impaired postural control associated with epilepsy, thus predisposing the injury?

Poor postural control and seizures are closely linked and may share a common cause. In a controlled study of 52 participants [13] Colnat-Coulbois found that people with temporal lobe epilepsy were more likely to have poor postural control than healthy controls. It concluded that temporal lobe epilepsy and vestibular dysfunction may separately share temporal lobe pathology. The important role of AEDs/ASDs influencing postural balance was confirmed in a meta-analysis examining papers focused on the effect of drugs on postural control [14]. A case controlled study identified benzodiazepines and AEDs/ASDs as being amongst the drugs most closely associated with impaired postural control and subsequent increased risk of falls and head injury [15]. Although, it needs to be re-iterated the link between medication and falls does not imply causation.

Similar findings were reported in a twin and sibling matched pair study (n = 29) that investigated chronic AED/ASD use and the risk of falls. Postural balance performance was impaired in AED/ASD users compared to their matched non-user siblings [16]. A larger twin study (n = 150) also examined balance impairment and AED/ASD use. Assessment of balance in the non-identical twin and in the matched sibling pairs found that AED/ASD poly-therapy (p = 0.007), longer therapy duration (p = 0.001) or recent falls were all risk factors for further falls and fractures. Multiple drug therapy and a longer duration of AED/ASD use are especially associated with impaired balance performance [17,18].

However, the relationship between mobility, postural control, epilepsy and AEDs/ASDs is a complex one. There are findings that: seizure frequency; total number of seizures; seizure type; duration of treatment; number of AEDs/ASDs; age of onset; presence of cognitive dysfunction and epilepsy in remission all contribute to balance and gait problems [19]. Quite independently of seizure control or AED/ASD use, people with epilepsy have been shown to have significant alterations in balance and mobility [20]. Again, the available studies have focused on association and not on causation.

3.5. Is age a risk factor for seizure related head injuries?

Age is an interesting dimension in relation to seizure related head injury because the prevalence and causes of seizures can change with age. The first year after the onset of seizures is a particularly high risk period for accidents at any age even after adjusting for comorbidities

(HR = 1.39, 95% CI = 1.30–1.49), [8] Children and adolescents with epilepsy are at particular risk of head injury compared with their matched sibling controls as identified in a retrospective lifetime assessment study of 501 cases (30.0% vs 19.5%; p < .02). Interestingly, head injuries were the only type of injury found to be of increased risk in adolescents with epilepsy [21].

A ten year retrospective study of people over 65yrs with epilepsy, who had sustained injuries secondary to seizures (n = 18), recorded 615 seizures. The majority of the seizures recorded were generalized tonic-clonic seizures and only 3% resulted in injury of which 10% were head injuries. Even in older age the number of head injuries sustained in people with epilepsy was found to be quite small [22].

3.6. Is Intellectual Disability (ID) a risk factor for seizure-related head injury?

ID is a specific condition and by its very nature is associated with brain impairment and thus with an increased risk of seizure activity, [23] ID is also associated with a higher risk for repeated injury linked to tonic-clonic seizures (4.3, 95% CI 1.5–16.1) [5]. A study examining the prevalence of falls and its risk factors in 1515 adults with ID found nearly 25% of adults from the study were reported to have had one or more falls in the previous 12 months. The study concluded that the prevalence of falls for people with ID increased with advancing age but also associated risk factors for falls were: being of the female gender; co-morbid arthritis; having a seizure disorder; being prescribed more than 4 medications; using walking aids; and difficulty lifting [24].

3.7. Are cardiac causes a risk for seizure-related injuries?

Ictal bradycardia or asystole may be of significance for people with epilepsy who present with seizure related falls. A multi-center study identified 16 people with ictal bradycardia or ictal asystole, of whom 15 people had a history of sudden falls, fainting, or trauma. Fourteen were suited for treatment with AEDs/ASDs or epilepsy surgery. Seven patients (43.8%) were subsequently treated with a cardiac pacemaker. Of those people treated, 9 achieved absence of sudden falls, fainting, or trauma. The authors concluded drug-resistant patients who are unsuitable epilepsy surgery should be considered for implantation of a cardiac pacemaker. This may prevent sudden falls and trauma [25].

A single case study reported on a middle aged man who presented with temporal lobe epilepsy and refractory focal seizures. Ictal bradycardia followed by asystole and syncope were observed on ECG and the syncope had resulted in severe head trauma. A cardiac pacemaker was inserted and at nine months follow up the patient had no overt seizures,

syncope or traumatic falls. This case study suggests that implantation of a cardiac pacemaker may prevent ictal syncope and associated trauma [26].

3.8. Is anti-epileptic drug (AED) or antiseizure drug (ASD) use linked to a risk of falls?

A cross sectional study looked at AED/ASD-related bone health and fracture risk (n = 150 people with epilepsy and 506 health comparison subjects). The study found that non seizure-related falls were more frequent than seizure-related falls in people taking AEDs/ASDs. Females had a significantly higher prevalence of falls. People with epilepsy taking AEDs/ASDs and with longer-term AED/ASD exposure had a higher risk of falls and fractures. Overall, people with epilepsy taking AEDs/ASDs had a low awareness of the risks of falling and fractures [27].

3.9. What are the benefits of head protection in epilepsy?

It might seem obvious that wearing a helmet will offer protection from head injury. However, a study specifically examined seizure-related injuries in people with epilepsy wearing protective helmets [28]. Information was gathered on the incidence, type and circumstances of injuries sustained in a group of young people with epilepsy using protective helmets over a one year period. 33 students in a Residential Epilepsy Centre were enrolled in the study and provided with helmets. They all had severe and complex epilepsy with numerous co morbid factors. Seizure-related injury risk was found to be rare (4/1,000 seizures). Scalp and facial bruises were the commonest injury (51%). Helmets were worn in 46% of accidents and 68% of these incidents resulted in facial or scalp injuries in spite of wearing a helmet. Forty one per cent of incidents occurred when helmets were not being worn and 57% of these accidents resulted in facial or scalp injuries. It was concluded by the authors that Injuries continue to occur at a similar rate whether wearing a helmet or not.

Protective helmets can be specifically adapted to prevent maxillofacial injuries. A case study reported on how a helmet was adapted for a young man who repeatedly sustained trauma to the head after suddenly falling either forwards or backwards in a seizure [29]. A bespoke helmet and visor was designed for him which was lightweight and reinforced with a rigid thermoplastic material. The tradeoff between protection and appearance is a difficult balance to make, but in this case there were no further injuries and the helmet with its visor was tolerated by the person.

Although trauma to the head in people with epilepsy might be uncommon, it can be severe. A case of extreme dental trauma where an adolescent male fell in seizure and his incisors intruded into the labial bony plate. [30]. The suggestion was that advice on helmet and face-shield protection should be provided in this type of case.

3.10. What are the biomechanics of protective helmet design?

In the world of sports, particularly cycling, rugby, horse riding and boxing the biomechanics of head injury has been studied in some detail where direction and speed of impact has been considered in order to develop appropriate protective headgear. However, no studies concerning biomechanics were identified for headgear specific to people with seizures.

There appears to be no European or other agreed quality standard or BSI Kitemark® for seizure related head protection helmets. In some sports such as amateur boxing, head gear has been identified as potentially harmful and is no longer recommended. Sports such as cycling where the fall is likely to be at speed, helmets are designed to crush on impact and are therefore discarded following an accident. Horse riding helmets are made with a liner of high grade polystyrene which in turn is protected by a hard shell. The shell is designed to diffuse the impact over a

large area to allow the liner to reduce bruising to the brain by increasing the length of time it takes for the shock to meet the head. The brim of riding hats are also included in the standards and are designed to keep the sun from the rider's eyes without impeding vision [31].

There are currently several standards that affect protective head-wear. People who ride in heavy vehicles, motor cycles, sports cars, professional sports people or emergency services operators all require head protection that meet a standard drafted into National, European or International Standards (Appendix A) Protective hat standards in these areas continue to evolve as a result of improvements in technology and developments but are noticeably absent from seizure fall protection.

3.11. What are the cognitive outcomes for people who sustain head injury in seizure?

A recent article [32] summarised a 36 year Danish follow up study of people with traumatic head injury irrespective of seizures. A 24% increase in dementia was reported in the head injury group compared with the general population with an escalating risk proportionate to the number of head injuries. A single 'mild' (not defined) head injury with concussion was linked to a 17% increase in dementia.

A review of the evidence considered that repeated seizure related traumatic head injury, even if 'mild' (not defined), might result in cognitive deterioration [33]. However, there are various pathways for this to occur including developmental issues, the adverse effects of treatment and seizures.

The frequency of severe generalised tonic clonic seizures was the best predictor of cognitive decline in a 10 year retrospective study of 136 participants. Seizure-related head injury and older age were associated with a particularly poor prognosis for decline in cognitive function [34].

4. Discussion

The focus of this review is specifically on seizure-related head injury. However it is important to recognise that people with epilepsy may fall and sustain a head injury from causes that are unrelated to the epilepsy or its treatment. There are many other medical conditions and other factors (for example being drunk) that can result in falls and do not affect "everyone". Most studies of seizure-related head injury are retrospective and the association between epilepsy and injury often relies heavily on patient and carer memory with the risk of recall bias. There is also the possibility that patients may disregard falls that they believe to be unrelated to epilepsy. The lack of a clear definition of head injury in most studies, together with a difficulty in distinguishing between a seizure-related fall and other falls, mean that statistically significant results presented in the papers included in this review need to be considered carefully, particularly in studies that have small numbers.

Epilepsy is increasingly seen as more than a simple alteration in brain activity. There are complex interactions between different parts of the brain and also wider effects that may alter cardiac and other physiological functions. This also applies to head injury linked with seizures where the research does not indicate why this is relatively rare or what the specific causes might be.

The role of cardiac influences on seizure related falls requires further research. Cardiac-related causes, even if seizures result from them do not necessarily reflect diagnosed epilepsy. The literature on ictal bradycardia or asystole is limited and consists of single case reports or small case series. There are no guidelines for the care of people with ictal arrhythmias where the arrhythmia may be a factor in the loss of postural tone and resulting head injury. It is therefore important to consider this possibility in cases of seizure-related head injury where inserting a cardiac pacemaker may prevent life-threatening cardiac arrest, syncope and head trauma in people with seizures. Patients with epilepsy will have comorbidities which may include cardiac problems producing dysrhythmias, which in their own right may cause transient

loss of consciousness, some with convulsive features and falls.

It is striking that there are no national standards regarding head protection for seizures. This may reflect the relatively infrequent need for head protection, because only a small percentage of seizures result in head injury. On the other hand, there are clearly some people who may sustain really severe or frequent trauma where clear guidelines for the construction of protective helmets would be helpful.

To date there are no long term studies on the wearing of head protection to prevent seizure-related head trauma. It is therefore difficult to draw any general conclusions about the risk and benefits of wearing a protective helmet and whether there is any benefit for long term cognitive outcome. At the same time there is a lack of detailed research regarding the biomechanics of seizure-related head injury. Nevertheless, patients and carers need to be aware that the signs of concussion, on the one hand, and post ictal confusion, on the other hand, can be very similar. It is important to be vigilant if someone has fallen and hit their head, even if wearing a helmet, and consider if they may have also been concussed. This point has significant implications for carer training in epilepsy awareness.

An important theme in this review is the role of AEDs/ASDs and their possible contribution to an increased risk of head trauma. The consistent finding is that the greater the number of AEDs/ASDs and the higher the dose, the higher the risk of head injury through their effect on postural control. In addition, the risk of seizure-related head injury needs to be carefully balanced with awareness that it is not always possible or necessarily desirable to stop all seizure activity. Ever increasing numbers or doses of AEDs/ASDs may actually cause recurrent falls and head injury. Poor postural control as a cause of head injury may be more of a risk factor than seizure type and easily missed. There are a number of brain pathologies that may cause seizures but may also affect postural control or occur independently.

Although no studies identified the stigmatising effect of wearing a helmet in everyday situations, it is a potential problem because people with epilepsy are vulnerable targets for stigmatising attitudes. Similarly, no studies were found that examined if quality of life was affected by wearing a helmet. These factors can have a powerful influence against the wearing of a protective helmet. It is interesting to note that, although there are other medical conditions that may result in falls and head injury - epilepsy seems to be the only condition where head protection is commonly recommended.

5. Limitations of this review

The review design does not specifically look into certain predisposing factors such as neurodevelopmental brain anomalies, genetics and other factors of brain dysfunction which may result in epilepsy that

is difficult to control and may also predispose to falls. The evidence of bradycardia predisposing to seizures and/or falls has not been interrogated. There is recognition that arrhythmias that are not a manifestation of seizures can cause syncope and falls and can also precipitate seizures. This was felt outside the scope of this paper.

6. Conclusion

Although significant head injury in a seizure affects very few people, helmets may have a substantial protective role, but helmet design for seizures is still in its infancy and there are no International Standards specifically for seizure-related head injury protection devices. The materials and style of current helmet design are always a compromise between total protection and being comfortable to wear, and it is important that there is continued study and development in this area. Head protection in epilepsy needs to strike a balance between the degree of risk and quality of life. Future helmet design should be based on carefully-analyzed data that ensures that real protection is offered for each individual according to seizure type and other relevant factors.

Conflict of interest

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Data sharing

Data sharing is not applicable to this article as no new data were created or analyzed in this study.

Appendix A. (Health and Safety Executive, European standards and markings for head protection)

	European standard	British standard where not harmonised
Industrial safety helmets	EN 397:2012	
Helmets for firefighters	EN 443:2008	
Industrial bump caps	EN 812:2012	
Helmets for pedal cyclists and users of skateboards and roller skates	EN 1078:2012	
Helmets for equestrian activities	EN1384 1996 / BSEN 1384 1997	
Mountaineering equipment	EN 12,492:2012	
Protective helmets for vehicle users. This standard is for motorcycle helmets		BS 6658:1985
Helmets for airborne sports	EN 966:2012	
Head protectors for ice hockey players	EN 967:1997 EN ISO 10,256:2003	
Impact protection helmets for young children.	EN 1080:1997	
Helmets for canoeing and white water sports	EN 1385:2012	

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