■ Review article

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Evaluation of EEG training curricula for non-specialist clinicians: a systematic qualitative review

Veena Kander[1], Joanne Hardman[3], Jo M. Wilmshurst[1,2]

[1] Department of Neurophysiology
[3] Department of Education, University of Cape Town,
[2] Department of Paediatric Neurology, Red Cross War Memorial Children's Hospital, Neuroscience Institute, University of Cape Town, South Africa

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ABSTRACT

Objective. Neurologists and epileptologists are scarce in sub-Saharan Africa (SSA). Whilst electroencephalograms (EEGs) are becoming more available in the region, interpretation is typically undertaken by non-specialist clinicians with limited or no training. This is a systematic review of the peer-reviewed literature on EEG training of non-specialist clinicians worldwide, assessing the efficacy of the training methodology and the curricula content.

Methods. The published literature was searched for papers relating to EEG training of non-specialist clinicians worldwide (1/01/1989-30/06/2020). All regions of the world were included and assessed for content on efficacy of curricula and potential adaptability or applicability to resource-poor settings. The grey literature was searched using ProQuest and Primo databases and references from review articles. The websites of the International League Against Epilepsy, International Federation of Clinical Neurophysiologist, American Academy of Neurology and World Federation of Neurology were reviewed for reports (non-peer reviewed) which described roll-out and impact of novel EEG training curricula.

Results. There was limited data. From 2,613 articles, 15 complied with the study question. Ten studies were performed on cross-speciality clinicians, four on neurology registrars and one on a combination of healthcare workers. There was diversity of curricula models used. The studies themselves lacked consistency and directness. A few training programs were trialled in low-middle-income countries (LMICs) and paediatric training was included in only two. An ideal training curriculum was not evident nor evaluated for resource-poor settings. However, diverse teaching models were reported and set the foundations for further development of EEG training curricula for non-specialist clinicians.

Significance. There is a lack of access to education in EEG training and interpretation for non-specialist clinicians in LMICs. Existing models need to be expanded or adapted and evaluated for this population group.

Key words: electroencephalography; EEG; curriculum; efficacy; education; teaching

• **Correspondence:**
Veena Kander
Department of Paediatric Neurology,
5th Floor ICH,
Red Cross War Memorial Children's Hospital,
Klipfontein Road,
Rondebosch,
Cape Town, 7700 South Africa
<veena.kander@uct.ac.za>

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Sub-Saharan Africa (SSA) has the highest prevalence of active epilepsy [1]. Many countries in SSA either have no neurologist or so few that neurological needs cannot be met for the affected population [2]. In 2016, a survey explored access to adult and paediatric neurology training programmes and found that out of 17 sub-Saharan African countries, there were 0.6 neurologists per million people [3]. Adult neurology with EEG training programmes were available in Burkina Faso, Cameroon, Republic of Congo and Mozambique whilst South Africa, Senegal, Ethiopia, Madagascar and Nigeria offered adult and paediatric training programmes with EEG components [3]. In North Africa, Morocco, Tunisia and Egypt have access to neurology training programmes (https://wfneurology.org/training-centres ; https://www.stneuro.tn/en). The University of Dakar, Senegal in West Africa, has been training neurologists since 2000 [4], with the first epileptology diploma in Africa founded in 2010 [4]. According to the World Health Organization (WHO), there are only 0.002 paediatric neurologists per 100,000 population in low-middle-income countries (LMICs) [2]. The number of paediatric neurologists has increased over the last decade but still not to the level equivalent to the minimal recommended ratio per population as found in high-income countries (1 per 100,000) [2]. The lack of qualified paediatric neurology doctors in Africa is largely due to a shortage of training opportunities [5]. Many professionals must seek training outside of their home countries and do not return, a phenomenon known as the "brain drain" [6].

In resource-equipped, and high-income settings, access to trained neurophysiologists and epileptologists is routine. Centres with resources to follow detailed curricula in line with national and regional groups in high-income countries (HICs), such as those based in North America and Europe as well as countries such as Japan and Australia, ensure that qualifying practitioners are exposed to the breadth of knowledge required to be competent in the interpretation of electroencephalograms (EEGs) *e.g.* (https://www.urmc.rochester.edu/education/graduate-medical-education/prospective-fellows/neurophysiology-fellowship/curriculum.aspx). Understanding the efficacy of these curricula is important to measure. Adapting such curricula for use in resource-limited settings is an additional challenge. In many LMICs, there is marked variation regarding who performs and interprets EEGs, from clinical medical officers and nurses through to adult neurologists and psychiatrists [7]. There is a lack of consistency in the training for these health practitioners. EEGs, when available, are often interpreted by personnel who have no or little experience in their interpretation, especially studies performed on children [8, 9].

A misinterpreted EEG recording can have significant implications for patient care, with the potential of erroneous labelling of a predisposition to epileptic seizures or missing an epileptogenic recording, leading to over- or under-treatment, respectively [10]. Over-reading normal variants and non-epileptic transients is amplified by lack of EEG training [10, 11]. Whilst all neurologists should have EEG training during their residency, this exposure can be limited and affect their ability to interpret EEGs [10, 12-14]. As gold standard practice, all neurologists should be trained to read EEGs performed on children and adults. Once the label of epilepsy is suggested by an official report, it is very difficult to withdraw this perception [10]. The diagnosis of epilepsy relies on documenting a thorough and consistent clinical history. The more experienced the clinician, the less frequently EEGs are requested, in comparison to junior or general medicine clinicians who are more inclined to automatically order the test under the assumption that the study is essential for diagnosis and management of epilepsy [10, 15].

EEG is a complicated field, especially in the paediatric age group owing to brain maturation and the complexity of performing studies on children. Attaining effective EEG skills parallels Bloom's models on educational learning objectives [16]. Bloom's theory identifies domains of learning around cognitive skills, *i.e.* learning, thinking, and understanding a subject. The importance of basic theory is fundamental to creating an EEG interpretation. Having a solid core foundation would allow clinicians to be able to interpret both adult and paediatric EEGs.

EEG is a non-invasive intervention which is inexpensive compared to other screens, such as neuroimaging, and with its high sensitivity and specificity remains the most widely used test for neural function [17]. When used appropriately, it can be a valuable diagnostic tool to support the diagnosis of epilepsy and to aid patient management [11, 18]. However, in many LMICs, the cost of an EEG (mean value: $24) remains beyond the capacity of the local population.

The aim of this review is to collate and analyse the published data which evaluates the efficacy of existing EEG training programs for non-specialist clinicians. For the purposes of this report, the term "non-specialist clinician" encompasses any practitioner who has not undergone a formal specialist epileptology training curriculum. Ideally, this analysis would direct how best to understand the most effective models for curricula and teaching formats of EEG training programs for this group of clinicians. Lastly, we aim to investigate which curricula have been or could be effectively adapted for LMICs and especially those which include interpretation of EEGs performed on children. This review is not exploring training at the level of epileptologists but is a pragmatic look at the most effective way to train non-specialist clinicians who need to have skills in EEG reporting, inclusive of cross-speciality clinicians who require some specific EEG skills. This includes critique of "inhouse" training during residencies and critique / guidelines of optimal tools for this training. An additional aim is to document assessments of "external" learning aids and courses to either train or upskill knowledge in EEG reporting.

▼ **Table 1.** PubMed Search strategy.

#1	MeSH terms:	"Electroencephalography"[Mesh]
#2	Free text:	Electroencephalography OR electroencephalogram OR EEG OR electroencephalograms
#3	#1 OR #2	
#4	MeSH terms:	"Curriculum"[Mesh]
#5	Free text:	Curriculum OR curricula OR pedagogy
#6	#4 OR #5	
#7	MeSH terms:	"Education"[Subheading] OR "teaching ''[Mesh] OR "Learning" [Mesh]
#8	Free text:	Education OR teaching OR learning OR training
#9	Free text:	train OR instruction
#10	#7 OR #8 OR #9	
#11	Free text:	Efficacy OR result OR results OR outcome OR outcomes
#12	#3 AND #6 AND #10 AND #11	
Outcome:		
#13	Filter	Date 01/01/1989-30/06/2020 Language - English

Methodology

Search strategy

A systematic review was undertaken independently by a senior librarian and the researcher using standard search terms. The following terms (*table 1*) were searched using key words and MeSH terms and were combined using Boolean operators. A search was performed on the following databases:
- PubMed – Medline;
- Scopus;
- Web of Science (Core collection and SciELO);
- and EBSCO Host (ERIC, Academic Search Premier, CINAHL, Africa Wide).

Phase 2 consisted of a grey literature search for additional reports not captured through the initial screen using the Primo data bases (articles and dissertations), Google scholar (first 20 pages) and the references of review articles which met the study inclusion criteria.

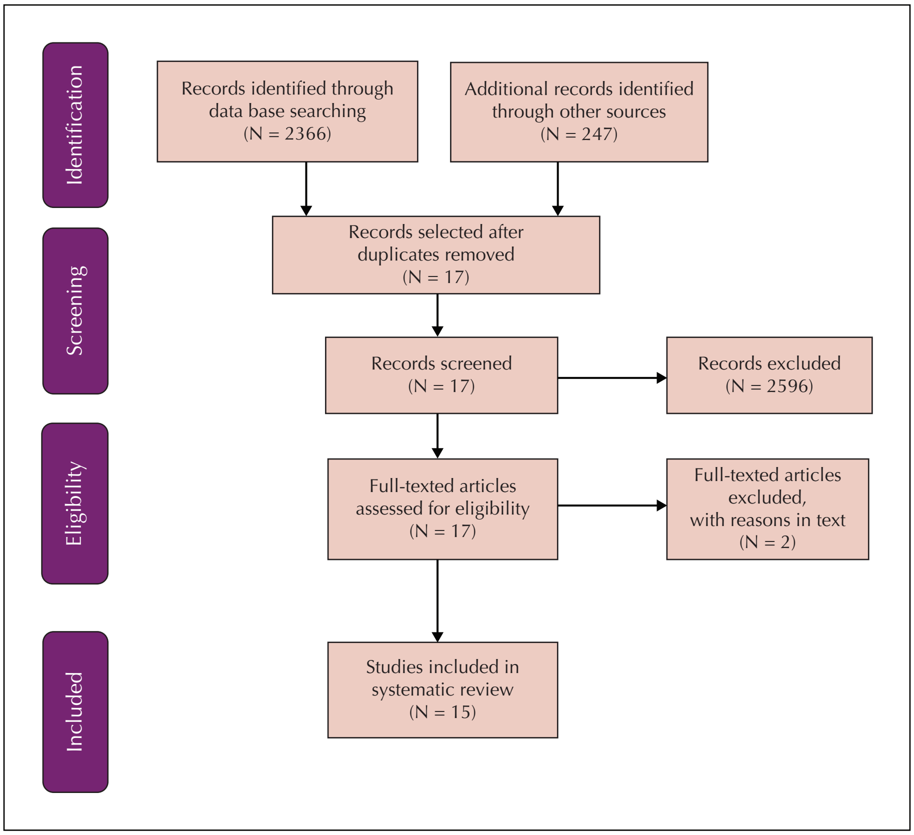
Only peer-reviewed studies published in English between 1st January 1989 and 30th June 2020 were included in the review. Few papers were identified which addressed the evaluation of the efficacy of EEG training curricula. Wider exploration of the topic through non-peer reviewed sources identified more data but little cohesion across these groups as well as with the grey literature search. The PubMed search strategy is outlined in *table 1* and prism flow diagram is presented in *figure 1*. The study was registered with PROSPERO (CRD42020189040).

In addition, a search was performed based on the websites of the International League Against Epilepsy (ILAE), International Federation of Clinical Neurophysiologist (IFCN), American Academy of Neurology (AAN), World Federation of Neurology (WFN) online courses (*e.g.* South Africa), Global Organisation of Health Education (GOHE) and via an independent neurophysiology training consultant (Academy of Neurodiagnostic Technology) for reports (non-peer reviewed) describing rollout and impact of novel EEG training curricula (*table 2*).

Inclusion criteria

Our inclusion criteria encompassed all studies in English assessing the efficacy of EEG training curricula worldwide both for adults and paediatrics over the 30.5-year period, as presented in *table 1*. Articles were excluded that were not original (teaching/learning EEGs). Articles were selected based on content of abstracts for full review. This permitted identification of further grey literature selection for those papers that met the inclusion criteria. The above text summarizes the literature identified including reports from websites, correspondence and major associations. We felt it was important to illustrate the impressive range of resources available but were unable to include these courses in the study as the efficacy of the curricula had not been measured. These resources could still provide valuable sources of support and guidance for the development of LMIC-applicable curricula tools. Furthermore, we included articles on experts with cross-speciality as recognition of EEG waveforms is compulsory in their practice.

Units of analysis presented as core common themes and trends that the researcher identified and coded accordingly (*table 3*): Population studied related to the



■ **Figure 1.** Prism flow diagram.

trainees, *i.e.* sample size, type of trainee health care practitioner; Interventions equated to curricula followed, number of EEGs used in testing, adult versus paediatric EEGs and type of trainer; and Comparators related to knowledge gained as assessed by pre-training assessment, *e.g.* multiple choice questions/written exam, and post training assessment also with multiple choice questions/written exam/pattern recognition. The outcomes were then collated in the discussion as the most effective methodologies and curricula used to be adapted for competency in EEG interpretation suitable for LMICs (*figure 2*).

Population	Non-specialist clinicians*
Intervention	EEG training in LMICs
Comparators	Knowledge before and after EEG training
Outcome	The most effective methodologies and curricula used for competency in EEG interpretation suitable to LMICs

**Non-specialist clinicians equate to healthcare professionals who are not specialists in epileptology*

■ **Figure 2.** Population, Intervention, Comparison, Outcome (PICO).

▼ **Table 2.** Websites for non- peer review reports.

Source	Teaching course	Teaching format	Target group	Outcome measures
International League Against Epilepsy (ILAE) https://www.ilae.org/files/dmfile/Announce_EEG-Basic-20191.pdf	VIREPA - EEG Basic1: The role of EEG in the Diagnosis and Management of Epilepsy	The course has 9 units, one-week introduction to the VIREPA e-learning platform, followed by 7 learning units of three weeks each and a final task unit	A minimum of 4 months of practical experience with clinical EEG is required as well as 3 years of training in neurology, neuropediatric, clinical neurophysiology, psychiatry or neurosurgery, or combinations	Tasks completed within an active online communication process among all participants, guided by the experts in the discussion forum on the e-learning platform.
	Epilepsy education (EpiEd)	The web based educational tool comprises seven domains and three levels (entry, proficiency and advanced proficiency)	Neurologists/ healthcare professionals of all levels/ allied health professionals/nurses/ care givers and governments	Awards a certificate on participants who meet the performance, proficiency or passing standard for assessments
	SCORE EEG Educational Platform	SCORE EEG is an interactive web-based training platform where students can practice their EEG-reporting skills. They can also compare their EEG findings to the findings of an EEG expert	Clinical neurophysiologists/ Epileptologists	
	The Asian Epilepsy Academy (ASEPA)	EEG course was established in 2000. Part 1 (written), consists of 150 questions Part 2 (oral), two 30-minute sections	Practicing neurologists or psychiatrists, neurology, epilepsy or EEG trainees and experienced EEG technologists	On passing both parts, the participant may become a certified electroencephalographer
International Federation of Clinical Neurophysiologist (IFCN) https://www.ifcn.info/courses.asp	Special Interest Group (SIG) will lead the educational program	Online teaching resources, teaching stands in congresses	Training of clinical neurophysiologists and visiting fellows	

▼ **Table 2.** Websites for non- peer review reports (*continued*).

Source	Teaching course	Teaching format	Target group	Outcome measures
International Child Neurology Association - virtual learning environment (ICNApedia) https://icnapedia.org/vle/	Online paediatric course	Consists of 10 chapters with a quiz after each chapter. Chapter 11 consists of 16 examples of real-life scenarios where knowledge can be tested. This course is self-paced.	Paediatric neurologists/ residents, neurophysiologists and non-specialists interested in learning basic paediatric EEG interpretation	Certificate on completion
Study EEG Online, University of Cape Town, South Africa https://studyeegonline.com/	EEG online distant learning	A part-time course, which runs for 6 months, and consists of 9 modules lasting 3 weeks.	Neurology/ neurophysiology trainees in clinical EEG	Certificate on completion NB: course has been evaluated but report is still pending
Academy of Neurodiagnostic Technology (acadndt) by Maggie Marsh-Nation	Online EEG portal	18-month course consists of 12 modules with a quiz after each module. The course is self-paced.	Neurophysiologists/ EEG technicians/ Neurologists/ residents	Certificate on completion
The Global Organization of Health Education (GOHE)	EEG workshops and online teaching with paediatric content	Face to face teaching plus online teaching resources. To date, GOHE has established projects in Ethiopia and Nigeria and a congress in India.	Training technologists in sub-Saharan Africa and in low or low/middle-income countries	Certificate on completion with progress towards the American Board of Registration of Electroencephalographic and Evoked Potential Technologists (ABET)

Results

A total of 2,366 articles (28/05/2020-29/06/2020) were found on the initial screening and 247 on a grey literature search. Two relevant articles were identified during a hand search for the author Fahy, who was notable for extended research into EEG curricula. Following abstract review, 17 articles were identified for full text exploration. Two articles were subsequently excluded, despite addressing EEG teaching; one was a survey of a video-based EEG curriculum [19] and the other was an overview which combined the studies by Fahy *et al* [20] and were already captured in the study. Whilst many opportunities for training were identified from websites, correspondence and major associations, without supporting data to evaluate the efficacy of the modules used, it is difficult to gauge the relevance, use and viability of the training across all settings. As a result, these were not included in the analysis but were expanded in the discussion, and are presented in *table 2*. For some of the programs, the webpages and news report highlighted teaching activities, but detailed training content format and outcome data were lacking. This was the case for the WFN and AAN initiatives in which there are active collaborations and promotions of neurology training in Africa, but further information for EEG courses was not available.

Fifteen studies met the inclusion criteria and are summarised in *table 3*. The researcher used quantitative descriptive statistics to analyse the articles. The studies were assessed and evaluated based on the descriptive statistics of similar core themes identified in each article as mentioned above - trainees, curriculum, EEGs, adult or paediatric practice, pre- and post-testing (n=15).

▼ Table 3. A systematic review of the peer-reviewed literature on EEG training of non-specialist clinicians worldwide based on the following themes (trainees, curricula, EEGs, adults or paediatrics, pre- and post-testing [n=15]).

	Population	Interventions					Comparators				
Study	**Trainees**			**Curriculum**	**No of EEGs used in testing**	**Adult versus paediatric EEGs**	**Pre-training EEG skills assessment**	**Post-training assessment**		**Statistical significance of training outcomes**	
	Sample size	**Time of EEG training**	**Epileptologist/ Neuro physiologist**				**MCQs/written exam**	**MCQs/written exam**	**[2]Pattern recognition**	**Pre-test mean values**	**Post-test Mean values**
[1]Fahy *et al.*, 2008 [21], USA	N= 33 Anaesth residents N=7 Had evaluations before and after in the in-depth EEG exposure N=12 Had new educational exposure N=14 Had traditional teaching without in-depth EEG exposure	1 Month	Neurophysiologist	Covered a wide range of theory:- 1) Basics of monitoring (general; dipole characters; electrodes; component requirements and montages), 2) physiological basics of EEG (maturation with age; changes with wake/sleep cycle; normal EEG tracing; recognition of artefact and abnormal EEG tracings, 3) clinical applications (epilepsy; coma; brain death; cerebral ischemia; prognostic indicator; burst suppression; anaesthetic effects and other effects).	11 EEGs pre and post-test	Adult EEGs	25 MCQ's including 11 EEG tracings of a 10s screenshot	25 MCQ's including 11 EEG tracings of a 10s screenshot		Mean scores (N=7) 10.7%	18.86% N=12 19.17% N=14 9.5%
[1]Fahy *et al.*, 2009 [22], USA	N= 8 Anaesth residents	1 Month	Neurophysiologist	Theory same as above	11 EEGs pre and post-test	Adult EEGs	25 MCQ's including 11 EEG tracings of a 10s screenshot	25 MCQ's including 11 EEG tracings of a 10s screenshot done after: -10 EEGs; 15 EEGs and 20 EEGs interpreted		Mean scores 8.0%	15.12% (10 EEGs) 15.88% (15 EEGs) 18.12% (20 EEGs)

Table 3. A systematic review of the peer-reviewed literature on EEG training of non-specialist clinicians worldwide based on the following themes (trainees, curricula, EEGs, adults or paediatrics, pre- and post-testing [n=15]) (*continued*).

[1]Chau *et al.*, 2010 [23], USA	N= 9 Neurosurgery residents	45-minute session	Neurophysiologist	Generators of EEG potentials, electrode placement and terminology, fundamentals of frequent bands, common artefacts, normal adult EEG and abnormal patterns (slowing, burst suppression and ictal patterns)	15 EEGs pre and post-test	Adult EEGs	25 MCQ's with 15 EEG tracings of a 10s screenshot.	25 MCQ's with 15 EEG tracings of a 10s screenshot.	Mean scores 12.0%	19.67%
[1]Meriem Bensalem-Owen *et al.*, 2011 [24], USA	N= 10 Anaesth residents	Two recorded 10-minute podcast sessions.	Neurophysiologist	Curriculum covered included clinical applications, physiological basis and monitoring.	10 EEGs post-test	Adult EEGs	25 MCQ's	25 MCQ's after podcast and then another 25 MCQ's after 10 EEG tracings of a 10s screenshot.	Mean score 9.50%	13.4%(podcast) 16.2% (10 EEGs)
Ochoa *et al.*, 2012 [31], USA	N= 15 Neurologists	6 Months		EEG recording technical concepts Montages and localization rules Normal EEG background, artefacts, and variants Abnormal EEG and clinical significance	40 EEGs		40 MCQ's	40 MCQ's Completed survey on program	Mean score 61.7%	87.8%
[1]Fahy *et al.*, 2014 [25], USA	N= 20 Anaesth residents N= 10 (10 EEG group + long term retention) N=10 (15 & 20 EEG group + long term retention)	1 Month	Neurophysiologist	Theory same as 2008 and 2009	10, 15 and 20 EEGs post-test	Adult EEGs	25 MCQ's with 11 EEGs	10 EEG group 25 MCQ's and 11 EEGs. 20 EEG group 25 MCQ's after 15 and 20 EEG's with 11 EEGs each. Long term retention (12 months) was tested with 40 item evaluation tools and 19 EEGs	Mean scores (N=10) 42.8% (N=20) 34.4%	63.2% Long term retention =6.9% 63.2% Long term retention=62.3%

Table 3. A systematic review of the peer-reviewed literature on EEG training of non-specialist clinicians worldwide based on the following themes (trainees, curricula, EEGs, adults or paediatrics, pre- and post-testing [n=15]) (*continued*).

[1]Chau *et al.*, 2014 [26], USA	N= 9 Pulmonary care fellows	4 Hours	Neurophysiologist	EEG potential generation, terminology and electrode placement, fundamentals of frequent bands, common artefacts, normal adult EEG (awake and asleep) and abnormal EEG patterns	10 EEGs pre and 10 EEGs post-test		25 MCQ's including 10 EEG tracing	25 MCQ's including 10 EEG tracing		Mean score 7.56%	Mean score 16.67%
Kander *et al.*, 2015 [18], SA	N= 11 Health care professionals N = 8 Paediatricians N= 3 Medical officers	5 Participants had 6 weeks to 24 months training 6 Had no training	Neurophysiologist	6 chapters covering: - 10/20 system, montages instrumentation, polarities, artefacts, waveforms, normal variants, activation procedures, epileptiform activity, reporting on EEGs, examples of reporting, epileptic disorders with illustrations and lastly a table on disorders from neonatal period to adolescence	40 EEGs of 100sec each (10 epochs) 20 structured EEGs 20 prospective EEGs	Paediatric EEGs	Reporting 10 structured and 10 prospective EEGs consisting of 10 epochs each	Reporting 10 structured and 10 prospective EEGs consisting of 10 epochs each after reading handbook Completed a survey on the handbook		Mean score Tutored (N=5) 47% Not tutored (N=6) 12%	(N=5) 74% (N=6) 32%
[1]Fahy *et al.*, 2015 [27], USA	N= 14 [Podcast group (medical students)] N= 10 (Control group – 1st year resident)	Two recorded 10-minute podcast sessions.	Neurophysiologist	Curriculum covered for both podcast and conventional didactics included basics of EEG, including EEG monitoring, physiological basis and clinical applications.	10 EEGs post-test		25 MCQ's for both control group and medical students	Podcast group: after podcasting and after 10 EEGs Control group- after 10 EEGs		Mean scores Medical students (N=14) 8.43% Control group (N=10) 9.70%	13.64% after podcast 14.86% after 10 EEGs 13.44% after 10 EEGs
Weber *et al.*, 2016 [32], USA	N= 20 Adult neurology residents	2 Weeks (12) and 4 weeks (8)	Epileptologist		20 EEGs pre and 20 EEGs post-test	Adult EEGs	35 MCQ's with 5 choices per question on a 10-15s EEG screenshot	35 MCQ's with 5 choices per question on a 10-15s EEG screenshot		Mean scores 42.7%	75.4%

▼ **Table 3.** A systematic review of the peer-reviewed literature on EEG training of non-specialist clinicians worldwide based on the following themes (trainees, curricula, EEGs, adults or paediatrics, pre- and post-testing [n=15]) (*continued*).

[2]Venkatraman *et al.*, 2016 [33], UK	N= 1 Neurology resident	1 Month	Epileptologist	EEG montages, lead placement and terminology	First 25 and last 25 EEGS of the 106 performed in one month	Adult EEGs			Statistical evidence increased for all findings accept epileptiform activity and posterior dominant rhythm		
[2] Dericioglu *et al.*, 2017 [11], Turkey	N= 11 Adult neurology residents	3 Months (5) and 4 months (6)			30 different EEG recordings of 10 sec epochs	Adult and paediatric EEGs			Self-limited and focal ictal onset patterns were the most difficult to recognize.		
[1]Fahy *et al.*, 2019 [20], USA	N=15 Critical care fellows (pulmonary, surgery and anaesth)	Web-based training module		EEG basics Clinical exposure EEG interpretation	10 EEGs		25 questions / evaluation tools	25 questions / evaluation tools		Mean score from baseline to after 10EEGs 2.8%	7.7%
[1]Fahy *et al.*, 2020 [29], USA	N=9 (Pulmonary n=5), (Anaesthetics n=2), (Surgery n=2)	Flipped classroom and screen-based simulation 50-Minute video podcast	Neurophysiologist	Theory same is Chau 2014	10 EEGs	Adult EEGs	25 questions / evaluation tools	25 questions / evaluation tools Participants completed a post-simulation survey		Mean score from baseline to after 10 EEGs 10.8 7.56	15.6 (simulation) 16.67
Legriel *et al.*, 2020 [30], France	N=180 Critical care staff (senior physicians, fellows, residents, medical students and nurses)	90-minute face to face EEG course	Neurophysiologist	Theoretical notions and illustrative EEG tracings	23s epochs or several minutes from cEEG	Adult EEGs	10-point EEG survey	10-point EEG survey at: - Day 1 Day 15 Day 30 -face to face EEG evaluation Day 90		Mean score Pre-test 3	Day 1 - 7 Day 15 - 7 Day 30 - 7 Day 90 - 8

[1]Study was performed nine times by the same group of authors.
[2]Pattern recognition as an informal means of post-testing.

Population

Out of the 15 articles, two target population groups were identified:
– clinicians learning EEG to diagnose seizures/epilepsy;
– and clinicians learning EEG for splinter skills required for cross-speciality clinicians, as described below.

For the former, four studies addressed the needs of neurology residents and one study addressed the needs of a combination of healthcare workers (paediatricians, neurology registrars and medical officers). For anaesthesiology and other cross-speciality clinician training, the Accreditation Council for Graduate Medical Education (ACGME) requires EEG monitoring experience to identify critical and clinically compromising rhythms (https://www.acgme.org). For the latter, the remaining 10 studies mostly addressed outcomes for anaesthesiology as well neurosurgery residents, medical students, critical care fellows (pulmonary and surgery) and intensive care unit (ICU) nurses [21-30]. Only one study was undertaken solely with paediatric residents who originated from LMICs [18]. Of the 15 studies, only two studies were performed in LMICs whilst the remaining 13 were in HICs [11, 18]. Of the four studies which critiqued neurology practitioners' skills, three were performed in HICs and one on clinicians from LMICs [11, 31-33].

The trainees completing the courses consisted of a range of disciplines, including medical officers, paediatricians, neurology residents, neurologists "with limited experience", medical students, internists, anaesthesiology residents, as well critical care physicians/fellows (pulmonary and neurosurgery) and ICU nurses. Sample sizes in the studies were small with most ranging from one to 33 participants, and only one with 108 participants, which made interpretation of the results across all domains challenging.

Interventions: curricula

Fahy *et al*. [21, 22, 26] and Chau *et al*. [23, 26] in three and two studies, respectively, used the same curriculum; two reports did not include the curriculum content and the remaining eight reports had a variety of content subjects noted but none were complete or comprehensive (e.g. syllabus for clinical EEG) [34]. Although some curricula were repeated, none of the study designs were consistent. The duration of training varied across all articles (10 minutes - 41 months) with a median of one month. The results showed that in 10 of the studies, a neurophysiologist undertook the main teaching, in two an epileptologist and in three the teacher was not stated. There was no difference in outcomes whether training was with an epileptologist [32, 33] or a neurophysiologist [18, 21-27, 29, 30]. The face-to-face components included lectures and practical sessions [11, 18, 21 -23, 25, 26, 30, 33]. Those with podcasts consisted of two 10-minute and 50-minute recorded sessions [24, 27, 29]. Online teaching utilised either a handbook [18] or an online program [20, 31] as well as an interactive EEG database with the automated program [32]. The different curricula and methodologies caused some bias, limiting comparison across studies.

Number of EEGs

The total number of EEGs interpreted as part of the training ranged from 10 to 50. The diversity of the EEGs varied from 10 seconds to several minutes of epochs, from cEEG recordings to full EEGs (20-30 minutes). This would have resulted in a bias as those reading full EEGs or more epochs had an advantage over those with 10 or 23-second epochs.

Adult versus paediatric EEGs

One report addressed solely paediatric EEG learning [18] and another a combination; the remaining nine studies were focused only on adult EEGs. Four studies did not include details of the EEGs read.

Comparators

• ***Pre- and post-training EEG skill assessment***

EEG skills were assessed prior to training in 13 out of the 15 studies. A combination of multiple-choice answers, reporting EEGs and online surveys were given to test the skills of the participants. Bias was possible as prior EEG experience of participants was not necessary before commencing training. The key issue concerning skill assessment was that two studies did not perform pre- and post-testing, however, they used pattern recognition as an informal means of testing. In addition, three surveys were completed on the handbook, simulation and online course respectively. All the studies showed some measure of improvement in students' competency after training. The post-assessments supported a general trend that all the above EEG training systems improve knowledge but not the level of competence after two 10-minute sessions or one 45-minute session as per Bloom's theory. Only two studies addressed long-term retention of knowledge [25, 30].

Discussion

The outcome of this study to evaluate the most effective methodologies and curricula used for non-specialist competency in EEG interpretation suitable to LMICs was limited by the lack of data. Several core common themes and trends emerged, namely blended learning such as face to face, podcasts, automated, simulation and online teaching which were the most popular tools to teach EEG interpretation.

Our results show that only two studies were performed in LMICs and the rest in HICs. In most parts of the world, especially LMICs, EEGs are reported by non-specialist clinicians with limited or no training in EEG. As access to electrophysiology equipment is becoming more readily available in most LMICs, abnormal readings will increase owing to the lack of EEG training. To address this need, initiatives such as GOHE in conjunction with Maggie Marsh-Nation are upskilling the training of neurophysiologists in LMICs (*table 2*). Paediatric neurologists are few or completely absent in many LMICs. Interpretation of paediatric EEGs by untrained clinicians can be very daunting and detrimental to the patient if diagnosed incorrectly. The burden of epilepsy is highest in LMICs, however, if misdiagnosed or misclassified it can have a major impact on affected children [35]. Our findings showed that only two of the studies taught paediatric interpretation (*table 3*). Out of the non-peer review reports, only one course did not include paediatrics (*table 2*).

Owing to the requirement for EEG competence training for cross-speciality residents in the USA and in most HICs, 10 studies were performed on this group. There was a marked lack of consistency in training for non-specialists compared to cross-speciality clinicians, although, none had the intention to train at the level of an epileptologist but rather to ensure competency in reading EEGs. ACGME has only a few specific requirements for clinical neurophysiology (CN), however, some neurology residents are graduating without meeting these milestones [14].

This study showed that EEG interpretation was not only taught to neurologists, but to professionals with a wide range of disciplines who are required to learn how to interpret EEGs. For comprehensive patient care, rather than acute interventions, for example as occurs for anaesthetics and intensive care, EEGs should be interpreted by neurologists. This supports the need for minimum EEG training for neurology residents during their rotation in terms of quality (supervision by an epileptologist) and quantity (months and number of studies) [10]. There is a knowledge gap in basic sciences especially EEG training for neurology residents [12-14, 36]. EEG interpretation is a difficult concept to learn as it not only involves pattern interpretation but an understanding of the disease process, clinical context and ability to communicate EEG findings to a non-specialist [22]. But it is expected that all qualified neurologists should be able to interpret EEGs [10]. Schuh *et al.* (2009) reported that the mean length of rotation a neurology resident in the USA spends in paediatric neurology and adult EEG attachments is 3.1 and 1.5 months, respectively. Inadequate exposure to subspecialty training, especially in neurophysiology, is a common trend [13, 14, 36, 37].

As such, there is a lack of formal teaching or dedicated time allotted to learn how to interpret EEGs for USA neurology residents [14]. Daniello and Weber [14] found marked differences in training durations from a few minutes to several years, and that some had no training but deferred to a "self-taught" handbook. The adequate training duration time is debatable and further compounded by time constraints for busy neurology residents. Some studies documented didactic training time included within residents' clinical schedules [32]. Many residents are not confident in reporting EEGs owing to the lack of time spent in neurophysiology [14]. Residents may lack the resources to undertake a fellowship in neurophysiology. Of clinicians training in adult neurology in the USA, only 25% planned to pursue a neurophysiology fellowship [13]. The added value of the subspecialty was questioned based on the effort and expense [38]. To adapt a curriculum for a less skilled and resourced population, a strong established format would ideally form the foundations for this process. It is worrying that there appear to be inconsistencies even within resourced and experienced settings.

Our study found there were vast methodological differences between the studies such as study design and sample size. Theory content varied from two topics to over six chapters in 13 of the articles and sample sizes were small in all except one study. Two studies did not document what theory was taught and as a result it is not known what basic theory each resident received [11, 32]. Although the theory of electrode placement was taught in some articles, there was no mention of the participants performing EEGs themselves and learning how to trouble-shoot (artefacts, machine trouble etc) in the studies. We found similar curricula topics being taught in both the non-peer review as well as in some of the papers being evaluated for example polarities which forms the core of EEG understanding [18]. This can strengthen the concept of what modules are important to understand EEG pattern recognition. The gold standard would be for a standardized curriculum and learning tool to be selected or developed to facilitate the best learning outcome for LMICs.

EEG examples covered were mostly from adults; only one study was on paediatrics and another a combination.

Four did not mention which examples were reported. This highlights how vulnerable children are in having their EEGs read by clinicians who lack training in paediatric EEG interpretation. Owing to the lack of paediatric exposure in this context, it would be difficult to achieve experience in this area. EEG interpretation is most effective based on pattern recognition, as such the higher the exposure to a variety of patterns the greater the successful yield of accurate interpretations [11]. Many studies used 10-23-second epochs for interpretation [11, 21-24, 30, 32], which would be challenging, if not impossible for one without experience. Further, a relevant clinical history and the state of the patient should be given before interpretation.

Using pre- and post-assessment skills enables evaluation of whether a student has gained knowledge. This was performed in 13 studies and two used pattern recognition as an informal way of testing. During EEG training, it is important to be exposed to all EEG waveforms, normal variants and key abnormal EEG patterns, assisting with diagnosis and treatment [11]. Infrequent normal variants and fluctuation of normal sharply contoured activity and artefacts can lead to over-interpretation of EEG and erroneous use of anti-seizure medication [9]. This is especially the case for the paediatric age group in whom over-diagnosis is as dangerous as under-diagnosis. Some settings, such as neonatology, are very complex and care is compounded by the expansion of increased on-site monitoring. As such, there is also an urgent need for neonatology EEG training programmes [39]. Only two studies addressed long-term retention which would reflect a better outcome evaluation. Although all improved in knowledge gained, demonstrating direct clinical impact from the training is more challenging to evaluate.

The outcome showed that the educational methods used in the studies were diverse. Podcasting proved to be a popular accessible tool available via internet at low implementation costs which could be explored to replace conventional teaching. However, podcasting alone is not optimal for learning. True learning, in the sense of cognitive development, requires that the student is actively engaged in constructing meaning; something that cannot be done through a monological podcast [40]. This was one justification for the lack of improvement found in one study [24]. As another tool, there was support for EEGs being taught via simulation as well [22]. Overall, trainees will still need interaction in order to develop their cognitive skills [16].

Study limitations

Whilst every attempt was made to cover search strategy for studies addressing evaluation of EEG training for non-specialist clinicians, only a limited number of articles were found for this review. Further, the majority of articles were performed on adult EEG interpretation and only one purely on paediatrics, with another on a combination. Another limitation of the study is that only two of the studies addressed the training of clinicians from LMICs and the rest were based in HICs. The latter concentrated on cross-speciality clinicians whom required some form of EEG training to be competent in their duties.

Conclusion

To answer our original question, we set out to understand what design curricula was being taught and what teaching strategies were used to upskill EEG interpretation for non-specialists. This study did not address established and expert specialist training, *i.e.* epileptologists. We found that further studies are needed to evaluate quality of current training and explore methods for adaptation to permit diverse introduction of teaching across all regions of the world. Based on the current data, it is not possible to state whether the above studies can address the need for non-specialist clinicians to learn a complex skill such as EEGs and to perform competently in their clinical practice.

Whilst exploring an effective model for learning the interpretation of EEGs, five different teaching methods were idetified. These included:
- face to face;
- podcasting;
- automated program styles of teaching;
- simulation;
- online programs.

There are many different teaching resources for EEG but only those which had been evaluated were included. As such, more studies are needed which are standardized to permit better analysis, to enable identification of novel teaching methods and systems that should be promoted and strengthened. The combination of face to face and online learning is a core teaching method to learn EEG interpretation [18].

Many online courses [18, 28, 31, 41] are yet to be critiqued. Collaboration is essential to fill the gap by working together in educating the African continent and other LMICs in safe EEG practice [42].

In conclusion, we did not find an ideal curriculum but found similarities with key concepts taught that can be adapted, to design an ideal curriculum and teaching strategy that should be viable for both HICs and LMICs. Our aim is to make non-specialist clinicians in LMICs competent in their knowledge in basic neurophysiology. This study found that paediatric EEG training is non-existent in some EEG training programs and as stated, few are based in LMICs. Owing to the rapidly developing field of technology, many of the future teaching methods could be undertaken online or via podcasts given the time restraints of residents (blended learning). ■

What this paper adds

1. Different models of formal and informal short courses of EEG learning are in use.
2. Four teaching methods were identified e.g. didactic / podcasting / online and automated teachings.
3. Paediatric and adult EEG learning tools which have undergone critique are scarce.
4. An effective or ideal model for teaching EEGs in LMICs has not been identified.

Ethical approval.
The study protocol was passed by the Red Cross Children's Hospital Research Committee and the University of Cape Town Ethics Committee REC/REF 481/2018.
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