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Benefit of educational intervention on Autoinjector Technique for caregivers and paediatric patients with food allergies: A literature review

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Abstract
Background and objective: The incidence of food allergy among children is on the rise. Children who are diagnosed with a food allergy receive long-term treatment for allergy management from allergy specialists, nurses and dieticians. This management may include the prescription of an adrenaline autoinjector (AAI) if the child is at risk of a severe allergic reaction (anaphylaxis). Therefore, it is important that parents of children with allergies are trained in the recognition of anaphylaxis and in the correct administration of an AAI. However, many parents are unable to correctly administer an AAI when assessed. The aim of this study is to review the current literature on caregiver's and paediatric patients' ability to use an AAI.
Methodology: An electronic search to evaluate AAI technique in caregivers and children with food allergy was conducted. A total of 323 articles were screened in which 10 studies were reviewed.
Results: Seventy-eight percent of parents who had never been trained in the use of an AAI were unable to trigger it. In studies where paediatric patients' ability to use an AAI was assessed, a mean score of 7.78/9 was derived for AAI knowledge among adolescents.
Conclusion: Caregivers and patient's ability to use an AAI was inconclusive, and further research should address the validation of an assessment tool for AAI use. A significant improvement in AAI use was found after an educational intervention. This highlights the need for improved education for allergic individuals and their caregivers, and further study should explore what are the best educational methods to meet these needs.

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Introduction

Children diagnosed with a food allergy require long-term follow up with paediatric allergy specialists, nurses and dieticians to understand the prevention and correct management in the case of accidental exposure which can produce a broad spectrum of allergic reactions.

Anaphylaxis is a severe allergic reaction associated with lower respiratory or cardiovascular features[1] that can be rapid in onset and occasionally fatal.[2] Although anaphylaxis is uncommon, the incidence is increasing, with the highest number of cases being seen in children and adolescents.[2] Mortality from anaphylaxis is uncommon yet well documented and is usually the result of hypoxia resulting from cardiovascular collapse, airway tract obstruction or pulmonary oedema.[3]

Adrenaline is the drug of choice for the treatment of anaphylaxis.[3] It is therefore recommended that children at risk of food-induced anaphylaxis have access to their prescribed adrenaline autoinjector, be it at home, school or out and about.[4] Parents and children who have been prescribed an adrenaline autoinjector (AAI) should be given instruction and guidance on when and how to use it by a trained healthcare professional.[2] However, many patients and caregivers are often unable to demonstrate correct administration of the devices when assessed.[2] This may reflect several issues including training effectiveness or lack of training, user stress during administration or inherent differences consequent of the design of the individual autoinjector.[2]

Aim

The aim of this literature review is to search for and appraise the existing literature related to administration techniques of adrenaline autoinjectors for caregivers and patients with food allergies.

Objectives

The objectives of this review are to:

1. Quantitively evaluate the administration techniques of adrenaline autoinjectors in caregivers and children diagnosed with food allergy.
2. Describe the effects of educational or training interventions on the administration technique of adrenaline autoinjectors in parents and children diagnosed with a food allergy.
3. Explore the factors which may influence the administration technique of adrenaline autoinjectors in caregivers and children with food allergies.

Methods

Search strategy

Two databases were utilised, namely PubMed and Wiley Online Library, to carry out an electronic search. This was carried out to identify literature with relevance to the research topic to achieve the above stated objectives.

The filters that were applied to both PubMed and Wiley Online Library search results are shown in Table 1.

Table 1 List of filters that were applied to PubMed and Wiley Online Library.

Number	Filter	Specification
1	Publication date	2000–2021
2	Language	English
3	Publication type	Journal

Inclusion and exclusion criteria

Due to the niche topic of this literature review, articles dating back to 2000 were used, many of which proved to be relevant and had they not been accounted for, would have resulted in a much narrower review of the chosen topic.

Several inclusion and exclusion criteria were applied to the search results obtained in both databases, which are outlined in Table 2.

Selection criteria

The initial PubMed search produced 14 results and Wiley Online Library search yielded 631 results, which were then condensed down to 13 and 323 results, respectively, after filter application. Of these 336 studies, 286 failed to satisfy the inclusion criteria. The remaining 50 studies were analysed in full to further refine the selection (Figure 1). A total of 10 articles were ultimately selected for the literature review.

The reasons for excluding articles during the screening and eligibility stages are outlined in Tables 3 and 4.

Validity of articles

All articles analysed in this literature review were critically evaluated using the EBL Critical Appraisal Checklist (Appendix A).

Results

Of the 10 studies selected for review, 5 were conducted in the UK,[2,4-7] 2 were conducted in Australia,[3,8] another 2 conducted in the USA[9,10] and 1 was conducted in Israel.[11] There was a range of sample sizes among the studies (60–188), with a mean of 115.5. The articles were analysed in the categories of population, study methodology, AAI assessment tool used, key findings and strengths and limitations. A summary of the 10 articles is shown in Table 5.

The average validity score using the EBL Critical Appraisal Checklist was 82.5%, with the validity scores in each section summarised in Table 6.

Table 2 Inclusion and exclusion criteria.

Inclusion criteria	Exclusion criteria
Articles with full online text availability	Articles without full online availability
Articles published between 2000 and 2021	Articles published before 2000
Articles published in the English language	Articles published in non-English language
Original research studies	Systematic review or meta-analysis
Studies with a population of caregivers and/or paediatric patients	Studies which did not involve caregivers or paediatric patients (e.g., adult patients, healthcare professionals, teachers)
Studies involving patients with food allergies who require the prescription of an adrenaline autoinjector.	Studies with patients who carry an adrenaline autoinjector for other medical reasons.
Studies which evaluate the administration technique of an adrenaline autoinjector.	Studies which only assess knowledge of allergies or allergic reactions.
Studies which assess adrenaline autoinjector administration technique with a demonstration or explanation.	Studies which only enquire about comfort with using an adrenaline autoinjector.
Studies which assess adrenaline autoinjector administration technique before and after an educational intervention.	
Studies which compare the administration technique and caregiver or patient preference of different brands of commercially available adrenaline autoinjectors.	Studies which compare the mechanical functionality of different adrenaline autoinjectors or assess adrenaline autoinjector administration technique to evaluate the functionality of prototype autoinjectors.

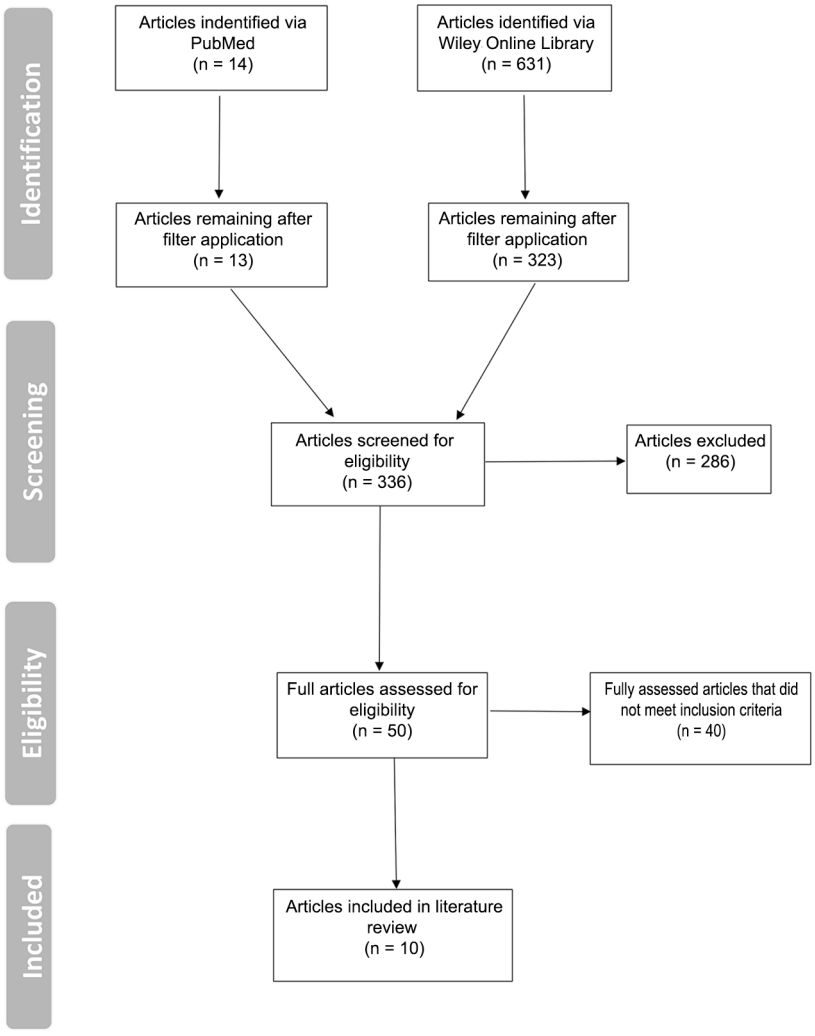

Figure 1 Flow chart outlining study selection from database search to studies included.

Table 3 Explanation for exclusion of articles during screening stage.

Explanation for article exclusion in screening stage	Number of articles
Articles not fully available online	138
Review articles or meta-analysis	36
Guidelines	20
Editorials or letters	23
Book chapters	11
Epidemiological studies	18
Immunotherapy for children carrying an adrenaline autoinjector	9
Assessment of pharmacist education for parents on adrenaline autoinjector administration	2
Conference meetings	8
Population of healthcare professionals only	10
Population of teachers only	4
Frequency of adrenaline autoinjector administration during anaphylaxis	7
Total	**286**

Table 4 Explanation for exclusion of articles during eligibility stage.

Explanation for article exclusion in eligibility stage	Number of articles
Adult-only patient population	5
Carry adrenaline autoinjector for other medical conditions	4
Assess knowledge on allergies and when to use an adrenaline autoinjector	8
Assess the carrying of adrenaline autoinjector habits among children with allergies	8
Assess incidence of accidental adrenaline autoinjector administration	5
Assess comfort in using an adrenaline autoinjector	5
Assess mechanical functionality of adrenaline autoinjectors	4
Assess the usability of prototype adrenaline autoinjectors compared to commercially available adrenaline autoinjectors	1
Total	**40**

Adrenaline autoinjector administration technique among paediatric patients and caregivers

All 10 studies assessed the AAI administration ability.[2,3–11] Seventy-eight percent of parents who had never been trained in the use of an AAI were unable to trigger it, while 35% of parents who had received a demonstration too failed to trigger it.[4] Twelve percent of mothers performed all 10 steps successfully with Epipen® compared to 32% of mothers with Anapen®.[2] Twenty-four percent of parents could recall all four steps of Epipen® in one study,[3] compared to 50% who could identify all three critical steps of Epipen® in another study.[6] Eighty-nine percent and 79% of parents successfully administered Epipen® and Anapen®, respectively, after 2 min of familiarising with them.[8] Eighteen percent of parents performed all six steps of an unidentified AAI administration correctly.[10]

In studies where paediatric patients' ability to use an AAI was assessed, there was a mean score of 7.78/9 for AAI knowledge among adolescents, and 18% could identify all nine steps correctly.[5]

Two studies compared AAI administration among both parents and patients.[9,11] In one study, 19% received a score of 0 when assessed in Epipen® use, while only eight (5.6%) scored the maximum 10 with a mean of 4.03 ± 3.[11] The other study reported that 32% of the participants demonstrated the use of the AAI correctly.[9]

The effect of a training or educational intervention on adrenaline autoinjector administration technique

Five studies compared the AAI administration technique of participants both before and after receiving an educational or training intervention.[6–8,10,11] A clinical nurse specialist educated the participating families on the usage of an Epipen®.[6] At baseline, 13 (50%) of those who were prescribed an Epipen® could identify all three critical steps, which improved to 22 (97.5%) after receiving the educational intervention, with an improvement of 83%.[6]

When participants were trained by an allergist in either Epipen® or Anapen®, 84% correctly demonstrated the use of the AAI before training (79.25% Anapen®, 89.26% Epipen®), which improved to 100% in both cohorts after training.[8] In a follow-up study 3 months later, the ability to recall Anapen® was 37% compared to 87% for Epipen®.[8]

When participants received written instructions and training from a physician on the use of Epipen®, the mean score of this subgroup improved from 4.71 ± 3.04 to 6.7 ± 3.18 ($P < 0.001$).[11]

When developing and validating educational materials for parents of children with allergies, ability to perform all steps increased from 18 to 95% after training (mean scores increased from 3.4 to 5.95, $P < 0.001$).[10] The mean score declined to 5.47 after 1 year, still significantly above baseline.[10]

Table 5 Summary of results of chosen articles.

Author (Year) Location Title	Objectives	Population sample size	Study methodology	Assessment tool used	Key findings	Strengths and limitations
Arkwright & Farragher (2006)[4] UK Factors determining the ability of parents to effectively administer intramuscular adrenaline to children allergic to food	To determine which factors are most strongly associated with the effective use of AAI.	Convenience sample of children who consecutively attended a single specialist paediatric allergy clinic in Manchester UK, between Nov 2004 and Aug 2005, who were diagnosed with a food allergy and prescribed an AAI. Parents of 122 children	Parents were given an Epipen® trainer pen and asked to demonstrate its use. Carers were assessed on their knowledge of using AAI in different situations, such as when a child had breathing difficulties or faintness. A survey was distributed to collect information regarding demographics, allergy diagnosis, prescriber of AAI, previous AAI training and previous allergic reactions.	Caregiver deemed unable to use AAI if they (1) had no idea how to use AAI (2) did not know the correct site to inject AAI (3) failed to remove safety cap (4) failed to apply enough pressure to trigger device or (5) took the needle out of the skin immediately after the device had been triggered.	Parents of children seen by an allergy specialist were more likely to be able to trigger the device than parents whose children had been seen by a GP or non-allergy specialist. 19% had never been shown how to use the device, and of these, 78% were unable to trigger it, compared to 35% who had been given at least one demonstration. Parents who attended an allergy self-help group were more likely to be able to use their AAI [4.4 (2.0–9.6) odds ratio (95% CI]. Parent of children who had an Hx of severe allergic reaction were no more likely to successfully use the AAI [4.8 (1.6–13.7) vs 4.8 (1.6–13.7) odds ratio (95% CI)].	*Strength:* 1. Large sample size of children FA. 2. Parents asked to demonstrate Epipen® use with trainer pen 3. Extensive study of parent and patient characteristics to determine their possible associations with AAI use. *Limitations*: 1. Data regarding what parents who could not fire the AAI failed to do not described. 2. Suggestions for further research not described.
Brown et al. (2013)[2] UK A randomised maternal evaluation of epinephrine autoinjection devices	To evaluate (1) maternal competence in using AAI following a standard anaphylaxis training package and (2) which out of the two devices was found to be easier to use by mothers	Mothers of children attending general paediatric outpatient departments and inpatient children's wards in one tertiary hospital with no previous AAI knowledge or experience. 100 mothers	Mothers were randomised to receive training in either Epipen® (n = 50) or Anapen® (n = 50). 30-min standardised individual demonstration on AAI use followed by immediate evaluation.	Evaluated by 10 pre-determined criteria. Six of these were common to both AAI. (1) Reassures and explains procedure to child, (2) removes child's clothes, empties pockets, (3) holds AAI in place for 10 s (4) massages site for 10 s, (5) places AAI in a safe place after removal, (6). phone 999. 4 was device-specific and taken from the manufacturer datasheet.	Overall, 15% of mothers were unable to "fire" AAI. 12 and 32% of mothers performed all 10 steps successfully with Epipen® and Anapen®, respectively. Higher proportion of mothers correctly performed all Anapen®-specific steps than Epipen® (OR 14.24, P < 0.0001)	*Strength*: 1. Large sample size with inclusion and exclusion criteria clearly defined. 2. Compared two brands of AAI used in clinical practice. 3. Results of each of the 10 steps in the evaluation clearly laid out. *Limitations*: 1. No follow up carried out 2. Not performed specifically on mothers of children with a food allergy. *3.* Removal of clothes an unnecessary step to evaluate.

(Continues)

Table 5 Continued

Author (Year) Location Title	Objectives	Population sample size	Study methodology	Assessment tool used	Key findings	Strengths and limitations
Gold & Sainsbury (2000)[3] Australia First aid anaphylaxis management in children who were prescribed an epinephrine autoinjector device (Epipen®)	To determine parental knowledge and AAI use for anaphylaxis management, the frequency of recurrence of allergic reactions, the measures that were taken and their outcomes	Parents of children with a Hx of anaphylaxis, who were prescribed with an Epipen® attended a paediatric allergy clinic between Jan 1998 and June 1998. 94	Telephone interview was conducted for parents to assess their knowledge on anaphylaxis, AAI use and allergic reaction prevention at home and school, allergic reactions since prescription of Epipen®, the symptoms experienced, actions taken and their outcomes (hospitalisation).	Four essential steps were used to assess AAI use. (1) removal of grey cap (2) placing the black end on the thigh (3) applying pressure until a click was heard (4) holding AAI in place for 10 s.	24% of parents could recall all four steps. 80% knew the administration site and to apply pressure. 50% removed grey caps and held in place for 10 s. Parents of children who had experienced a greater number of allergic reactions had a greater knowledge of AAI use. 37% of those whose children experienced two or more reactions performed all four steps compared to 18% of those who experienced one or fewer reactions.	*Strength*: 1. Population received the same education regarding AAI use and allergy knowledge prior to study. 2. Simple 4 step assessment tool for Epipen® use. 3. Links findings regarding AAI knowledge to use during anaphylaxis *Limitations*: 1. Assessment of AAI conducted over the phone rather than face to face.
Jones et al. (2015)[5] UK Factors associated with good adherence to self-care behaviours among adolescents with food allergy	To use the Health Believe Model to explore factors relating to self-care behaviours among adolescents with food allergies.	Adolescents aged 13–19 years, diagnosed with a food allergy and prescribed an AAI, who have attended one or two paediatric outpatients' clinics. 188	A questionnaire was given to participants with items based on the Health Belief Model. It contained questions regarding demographics, allergy diagnosis, knowledge on AAI use, confidence with using an AAI, support, social psychological factors, health beliefs, perceived susceptibility, perceived benefits, perceived barriers and cues to action.	Assessed with nine questions regarding anaphylaxis management with participants getting a score out of 9 for correct anaphylaxis management. Questions related to symptoms of anaphylaxis, preparing AAI (check expiry date, remove cap), administration (holding AAI correctly, through clothing, injection site, length of time to hold AAI in place) and follow-up care.	Mean of 7.78/9 score for AAI knowledge. 18% could identify all the nine steps correctly. Poorest level of knowledge in knowing how to hold the AAI (44% incorrect) and always seeking medical attention after using AAI (32% incorrect) Knowledge of AAI use not associated with adolescent self-adherence.	*Strength*: 1. Simple nine-mark scoring system to assess AAI use. 2. Assessed all aspects of AAI use, including before (recognising symptoms) during (correct AAI administration) and after (seeking medical attention). 3. Studies associations of AAI knowledge with other psychological and social factors relating to having a food allergy. *Limitations*: 1. Low response rate to questionnaire (34%) possible responder bias. 2. Knowledge assessed with a questionnaire with no demonstration. 3. Brand of AAI prescribed not specified in questionnaire.

Kapoor et al. (2004)[6] UK Influence of a multidisciplinary paediatric allergy clinic on parental knowledge and rate of subsequent allergic reactions.	To assess the impact of multidisciplinary allergy consultation in a specialised allergy clinic on parental knowledge of food allergy and the rate of subsequent allergic reactions.	Parents and children aged <17 years who attended a specialised allergy clinic and were diagnosed with a food allergy. *62*	Before attending the clinic, parents completed a questionnaire regarding allergen avoidance, anaphylaxis management and Hx of allergic reactions. Parents and older children were asked to demonstrate the use of Epipen®. Children were assessed by an allergy specialist, and an allergy management plan was set up for them. A clinical nurse specialist educated the children and parents on anaphylaxis management plan and how to use an Epipen®. A specialist dietician consulted them on food allergen avoidance. Parents filled in the same questionnaire and demonstrated Epipen® use at a follow-up appointment 3 months later and reviewed 1 year later.	Parents and older children were asked to demonstrate Epipen® use prior to and 3 months after consultation. Three steps were identified as being critical for Epipen® use: (1) removal of grey safety cap (2) selecting appropriate site and (3) pressing Epipen® down until a "click" is heard.	*Before consultation:* 60.7% of the families had received a demonstration on how to use their Epipen®. 50% could identify all the three critical steps, and there was no difference in those referred from primary or secondary care. *After consultation:* 95.7% of the families could identify all the three critical steps, with an improvement of 83.3%. Similar improvements were seen in families referred from both primary and secondary care. There were also significant improvements in parental knowledge of allergen avoidance (26.9%) and in management of allergic reactions (185.4%). These improvements were associated with a significant reduction in allergic reactions.	*Strength*: 1. Assessment of AAI use before and after an educational intervention by an allergy specialist. 2. Clear outline of intervention carried out. 3. Association of Epipen® knowledge with incidence of allergic reactions. *Limitations*: 1. Small sample size of parents assessed for AAI use (n = 23).

(Continues)

Table 5 Continued

Author (Year) Location Title	Objectives	Population sample size	Study methodology	Assessment tool used	Key findings	Strengths and limitations
Robinson et al. (2014)[8] Australia Comparison of adrenaline autoinjector devices: Ease of use and ability to recall use	To compare the intuitiveness of the use of Epipen® and Anapen® devices and the ability to recall the use of these devices after 3 months.	Visitors, parents and staff attending a children's hospital over a 3-month period, who had not received prior training in the use of Epipen® or Anapen®. 100	Participants were randomised to be evaluated with Anapen® (n = 53) or Epipen® (n = 47). Participants were given 2 min to familiarise themselves with the device before being assessed. Participants received training on the usage of AAI by an allergist, and they were asked to demonstrate the use of the device immediately after. 32 patients were contacted 3 months later and asked to demonstrate the use of the AAI.	Critical steps in Epipen®: (1) removal of blue safety caps (2) orange cap on upper and outer thighs (3) downward pressure to activate. Critical steps in Anapen®: (1) removal of grey safety cap (2) removal of black cap covering the needle (3) black needle end on thigh (4) pushing red button to activate. Also, select the upper and outer thighs and hold AAI for 10 s.	84% correctly demonstrated the use of the AAI with no previous training, and no significant differences were observed between the devices. 100% correctly used the AAI after receiving instruction. After 3 months, ability to recall the use of Anapen® was lower than that of Epipen® (35% vs 87%, respectively). Critical errors were more common in Anapen® than in Epipen® (59% vs 13%, respectively), with the most common critical mistake being made in Anapen®, which was failure to push the red button to activate.	*Strength*: Large sample size (n = 100) Inclusion and exclusion criteria clearly outlined. Specific errors in each device outlined. *Limitations*: Small sample size in follow-up study (n = 32) Allowed 2 min prior to assessment to familiarise themselves with the pen.
Segal et al. (2012)[11] Israel Effect of Instruction on the ability to use a self-administered epinephrine injector	To evaluate the knowledge on AAI usage in parents and patients with allergies after an initial clinic visit and assess the benefit of reinstruction in the use of Epipen® at a follow-up visit.	Children and adolescents and their parents attending an allergy clinic who had experienced anaphylactic reactions and were diagnosed with an Epipen®. 141	Patients and parents were given written emergency anaphylaxis plans and written instruction on how to use Epipen® and trained in its use by a clinician. At the next follow-up visit, participants were given a questionnaire on indications for use of an Epipen® and were asked to demonstrate	Each step of the procedure was given a score between 0 and 2, with a maximum possible score of 10. 0 meant that the participant did not know to do this. 1 meant that they hesitated for a period before completing the step. 2 meant that the step was performed correctly without hesitation.	37.5% of participants failed to remove the cap (Step 1). 62–87% incorrectly performed Steps 4 and 5. 19% received a score of 0. Eight (5.6%) scored a maximum 10 with a mean of 4.03 ± 3. 41 participants were re-evaluated after 1.02 ± 0.56 years. The mean score of this subgroup improved from 4.71 ± 3.04 to 6.7 ± 3.18 ($P < 0.001$).	*Strength*: Large sample size (n = 141) Assessment tool clearly defined. *Limitations*: Neither strengths nor limitations were discussed. Recommendations for further research were not discussed.

			its use with a trainer pen. Some participants were asked to repeat the demonstration at a second follow-up visit.	Steps: (1) Remove the cap (2) holding the device (3) placing on thigh and pressing until a click is heard (4) hold in place for 10 s (5) massage injection site.		
Sicherer et al. (2000)[9] USA Use Assessment of Self-Administered Epinephrine Among Food-Allergic Children and Paediatricians	To determine the ability of families with food allergic children and paediatricians to correctly use an AAI.	Families of newly referred food allergic paediatric patients who were prescribed an AAI. A sample of paediatricians at a paediatric ambulatory care facility and five private clinics affiliated with the same hospital. 101 families. 29 paediatricians.	Parents or teenage patients completed a questionnaire regarding demographics and the use of self-administered adrenaline. They were then asked to demonstrate the use of the AAI which they were familiar with.	Epipen® use was scored out of six steps based on the instructions supplied by the manufacturer. (1) recognises the device without examining for clues as to how to use it (2) remove cap (3) select appropriate body site (4) press the correct end of the device to body (5) press to activate 6) hold in place for several seconds.	32% of the participants demonstrated the use of the AAI correctly. The steps which accounted for the greatest number of mistakes were removing the safety cap (30% incorrect), pressing to activate the needle (click) (40% incorrect) and holding the device in place for several seconds (45% incorrect).	*Strength*: Large sample size (n = 101). Extensive study of parent and patient characteristics to determine their possible associations with AAI use *Limitations*: Results not clearly outlined. Neither strengths nor limitations were discussed. Recommendations for further research were not discussed.
Sicherer et al. (2012) USA Development and validation of educational materials for food allergy	To develop and validate a food allergy educational programme for parents.	Convenience sample of families presenting for their first visit to two allergy clinics who were prescribed an AAI. 60	Educational materials were developed through focus groups, and parental and expert reviews. Parents were asked to complete a demographics questionnaire and food allergy knowledge test. AAI administration was assessed before and after the educational intervention. At 1 year, the parents were re-evaluated.	AAI competency was scored out of a maximum of sox based on the following steps: (1) recognises device without looking for clues as to how to use it (2) remove cap (3) correct site (4) correct end (5) press to activate (6) hold for several seconds.	18% performed all six steps correctly prior to training. This increased to 95% after training (mean scores increased from 3.4 to 5.95, $P < 0.001$). The mean score declined to 5.47 after 1 year, still significantly above baseline, with two sub-scores decreasing significantly, namely recognizing the device and holding the device in place for several seconds. Comfort in using the AAI was based on a scale of 1 (not comfortable at all) to 7 (totally comfortable). The mean score at baseline was 4.63 and increased to 6.23 after the intervention and remained elevated at 1 year (6.03).	*Strength*: Assessment tool used in study included. Detailed summary of population demographics. Clear outline of educational intervention used. *Limitations*: AAI assessed was not identified. Small sample size (n = 60)

(Continues)

Table 5 Continued

Author (Year) Location Title	Objectives	Population sample size	Study methodology	Assessment tool used	Key findings	Strengths and limitations
Umasunthar et al. (2015) UK Patients' ability to treat anaphylaxis using adrenaline autoinjectors: A randomised control trial.	To evaluate the ability of mothers of food-allergic children to successfully use an AAI in a simulated anaphylaxis scenario and to compare success rates in mothers allocated to different AAI devices.	Mothers of children with a food allergy and prescribed an AAI attending a specialist paediatric allergy centre. 200	Participants were randomly allocated to be trained in either Anapen® or Epipen®. AAI administration and 6 weeks and 1 year after initial training. At 1 year, participants were allocated a new device (Epipen®, Anapen®, new Epipen®, Jext® or Auvi-Q®), and their ability to use the new AAI was assessed without prior device-specific training.	Four key steps were identified for success of AAI administration: (1) removal of safety caps (2) placement of correct end of device against the thigh (3) activation of device (4) holding device in place for >5 s. Primary reason for failure was defined using a hierarchy of safety cap(s) > correct device positioning > device activation > held in place for sufficient time.	No specific difference in success rates between Epipen® and Anapen® at 6 weeks and 1 year. At 1 year, Anapen® users were more likely to fail to remove the safety cap, while Epipen® users were more likely to use the incorrect end of the device. Difference in success rates for participants switched to a two-cap device (Anapen®) from a single-cap device (Epipen®, New Epipen®, Jext®, Auvi-Q®) or vice versa (36%) compared with participants switched between different single-cap devices (78%).	*Strength*: Large sample size (n = 158) All results clearly outlined Hierarchy of failure in AAI steps *Limitations*: Inclusion and exclusion criteria not clearly outlined

Table 6 Summary of validity scores of the selected articles using the EBL Critical Appraisal Checklist.

Study	Section A: Population	Section B: Data collection	Section C: Study design	Section D: Results	Overall score
Arkwright & Farragher (2006)[4]	83.33%	60%	80%	66.66%	72.7%
Brown et al. (2013)[2]	75%	57.4%	100%	100%	80.7%
Gold & Sainsbury (2000)[3]	66.66%	50%	100%	100%	78.2%
Jones et al. (2015)[5]	100%	80%	100%	100%	95.45%
Kapoor et al. (2004)[6]	100%	71.4%	100%	100%	91.7%
Robinson et al. (2014)[8]	87.5%	71.4%	100%	100%	88.46%
Segal et al. (2012)[11]	50%	57.1%	80%	66.66%	62.5%
Sicherer et al. (2000)[9]	83.33%	66.66%	100%	66.66%	78.26%
Sicherer et al. (2012)[10]	83.33%	66.66%	100%	100%	88.46%
Umasunthar et al. (2015)[7]	100%	71.4%	100%	83.33%	88.46%

In a study on AAI administration, it was found that successful AAI administration declined after switching to a new brand without receiving training (73.1–65.7%).[7]

Factors which affect adrenaline autoinjector administration technique

Differences in AAI design were discussed in three studies.[2,7,8] A higher proportion of mothers correctly performed all Anapen®-specific steps (32%) than Epipen® (12%).[2] This contrasts with the findings of another study,[8] where it was observed that significantly more participants correctly demonstrated Epipen® use (87%) compared to Anapen® (35%) 3 months after training, and critical errors were more common with Anapen® (59% vs 13%, P = 0.01). When switching to a new device without training, difference in success rates for participants switched to a two-cap device (Anapen®) from a single-cap device (Epipen®, New Epipen®, Jext®, Auvi-Q®) or vice versa (36%) when compared with participants switched between different single-cap devices (78%).[7]

The other factors observed by some studies which were found to significantly influence the ability of participants to administer an AAI included demonstration by a specialist allergist compared to a specialist or general practitioner {5.7 [2.0–16.3] vs 2.0 [0.9–4.9] odds ratio [95% confidence interval (CI)], respectively}[4] and membership in a lay organization or support group for allergy [4.4 (2.0–9.6) odds ratio (95% CI)].[4] Previous severe allergic reactions [1.0 (0.3–13.7) odds ratio (95% CI)][4] and time elapsed since last demonstration of AAI use [<12 months vs >24 months; 4.8 (1.6–13.7) vs 4.8 (1.6–13.7) odds ratio (95% CI][4] were not found to relate to the ability in AAI use.

Summary of results

Discussion

Findings on ability to use an AAI varied significantly, the success rates ranged from 5.6 to 84%.[8,11] However, the former low maximum success rate of the above study[11] is caused by the significantly high proportion (87%) of those who failed to massage the site after injection, a step which does not cause the failure of adrenaline administration, a limitation in this study's analysis. A limitation of the second study[8] was that the study population consisted of parents who were not familiar with the usage of AAI, and they were given only 2 min to familiarise themselves with using the AAI before assessment. Therefore, the findings may not represent the population of parents who are familiar with AAI devices but those who have not been given the chance to study in detail themselves how to use it, especially as this would not reflect a real emergency. There were no significant differences found between caregiver and adolescent patient AAI use, and the average score was 7.78/9.[5] However, a significant limitation in this study was that AAI technique was assessed with a set of multiple-choice questions, which was less accurate than the demonstration of AAI use.[5]

The wide range of reported AAI ability may be due to the varied tools to assess AAI use in their respective populations, as shown in Table 6. Lower quality articles failed to address those steps in AAI administration which the participants failed to do,[4] assessed AAI administration over the phone[3] or used a multiple-choice questionnaire.[5] Another lower quality study[11] emphasised the failure of many caregivers to perform the final two steps in the assessment (hold in place for 10 s, massage site after injection) which do not indicate that adrenaline administration had failed. Part of assessment included whether parents failed to remove clothes before injection, which in fact is an unnecessary step in AAI administration and may prolong the administration of adrenaline.[12] Studies of higher quality assessed AAI administration by using tools which evaluated fewer steps,[6,7] used device-specific steps for successful administration[6,8] and identified steps which were "critical" to the administration of adrenaline, which would result in an automatic failure of adrenaline administration.[7,8]

All five studies, which evaluated the effectiveness of educational intervention on AAI use,[6–8,10,11] found that AAI administration improved significantly. Three of the five studies[6,8,10] assessed the AAI ability prior, immediately after and several months after receiving the intervention. This method showed the long-term impact of the educational intervention on AAI delivery technique, and in all studies, AAI ability was above baseline even up to a year after the initial training. However, in one case,[8] baseline results were already high as the parents were allowed to familiarise themselves with the pen for 2 min before assessment,

and even though there was an improvement after training, it may not accurately reflect the true improvement from training. While another study[7] showed that switching to a new device without receiving training decreased the success rate of AAI administration, they did not carry out baseline evaluations of participants before they received training in the initial device. This limitation may question the validity of their results.

Apart from educational interventions, another factor influencing AAI administration that was explored in some of these studies was the brand or type of AAI used.[2,7,8] A higher proportion of participants successfully used Anapen® compared to Epipen®,[2] but the converse of this was found in another study.[8] However, the former study,[2] scored parents out of 10 possible steps, while the latter[8] marked out of 6 and 5 possible steps for Anapen® and Epipen®, respectively. The increased number of steps in their criteria may have affected the accuracy of these results by including steps that were unnecessary for the successful administration of the devices.

This review of literature highlighted some areas where further research is required. While all 10 studies assessed the ability to use an AAI, the wide range of assessment tools employed did not allow for accurate comparisons of the results; therefore, further study should be carried out to design and validate an assessment tool for AAI administration technique which can be applied to future studies when assessing caregiver and patient AAI use. In addition, other factors that may influence AAI ability, such as the influence of parental knowledge of AAI use on the child's knowledge to use AAI was not explored in any of the reviewed studies. Otherwise, this review covered a large cohort of the available research in this area.

There were several limitations identified in this review. The scope of this review was limited by the small number of studies reviewed. Also, only two online databases were searched, and it is possible that a significant number of relevant studies were missed by failing to search more databases. In contrast, strength of this review was that all the studies selected underwent rigorous critical appraisal and detailed analysis of their methodologies and findings.

Future perspective

The introduction of new technologies including new ways to administer adrenaline for anaphylaxis in the following years could drastically change the way that we use adrenaline autoinjector devices.[13]

Conclusion

Children are reliant on their parents to take responsibility of their allergy, to recognise the signs and symptoms of anaphylaxis, and to deliver adrenaline promptly.[2] The review of parents' and patient's ability to use an AAI was inconclusive, and further research should address the validation of an assessment tool for AAI use. However, a significant improvement in AAI use was found after an educational intervention, and this improvement was still seen months after the intervention was given. This highlights the need for improved education for allergic individuals and their caregivers, and further study should explore what are the best educational methods to meet these needs. Finally, AAI administration ability varied among different AAI devices; therefore, as more AAI brands come to the market, device switches could become a significant clinical issue,[7] and the rate of device switches and the effect this has on the ability to administer an AAI in an emergency should be investigated.

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Appendices

Appendix A: EBL Critical Appraisal Checklist

	EBL Critical Appraisal Checklist	Arkwright & Farragher (2006)[4]	Brown et al. (2013)[2]	Gold & Sainsbury (2000)[3]	Jones et al. (2015)[5]	Kapoor, S. et al (2004)[6]	Robinson et al. (2014)[8]	Segal et al. (2012)[11]	Sicherer et al. (2000)[9]	Sicherer et al. (2012)[10]	Umasunthar et al. (2015)[7]
Section A: Population	Is the study population representative of all users, actual and eligible, who might be included in the study?	Y	Y	Y	U	Y	Y	Y	Y	Y	Y
	Are inclusion and exclusion criteria definitively outlined?	Y	N	N	N	Y	Y	N	N	Y	Y
	Is the sample size large enough for sufficiently precise estimates?	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
	Is the response rate large enough for sufficiently precise estimates?	Y	Y	N	Y	Y	Y	Y	Y	Y	Y
	Is the choice of population bias-free?	Y	N	Y	Y	Y	Y	Y	Y	U	Y
	If a comparative study:										
	1. Were participants randomised into groups?										
	2. Were the groups comparable at baseline?										
	a. If groups were not comparable at baseline, was incomparability addressed by the authors in the analysis?	N/A	Y	N/A	Y	N/A	N/A	-	N/A	N/A	Y
	Was informed consent obtained?	U	Y	Y	Y	Y	Y	U	Y	Y	Y
Section B: Data Collection	Are data collection methods clearly described?	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
	If a face-to-face survey, were inter-observer and intra-observer bias reduced?	N/A	U	U	Y	N/A	U	U	U	U	Y
	Is the data collection instrument validated?	U	U	U	U	Y	Y	N	Y	N/A	U
	If based on regularly collected statistics, are the statistics free from subjectivity?	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Does the study measure the outcome at a time appropriate for capturing the intervention's effect?	N/A	Y	N/A	N/A	N/A	Y	Y	N/A	Y	Y
	Is the instrument included in the publication?	Y	Y	Y	Y	Y	Y	N	Y	Y	Y
	Are questions posed clearly enough to be able to elicit precise answers?	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
	Were those involved in data collection not involved in delivering a service to the target population?	N	U	U	Y	U	U	N	U	U	N

Section C: Study Design	Is the study type or methodology utilised appropriate?	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
	Is there face validity?	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
	Is the research methodology clearly stated at a level of detail that would allow its replication?	N	Y	Y	Y	Y	Y	N	Y	Y	Y
	Was ethics approval obtained	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
	Are the outcomes clearly stated and discussed in relation to the data collection	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Section D: Results	Are all the results clearly outlined?	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
	Are confounding variables accounted for?	N	Y	Y	Y	Y	Y	Y	N	Y	N
	Do the conclusions accurately reflect the analysis?	Y	Y	Y	N	Y	Y	N	Y	Y	Y
	Is subset analysis a minor, rather than a major, focus of the article?	Y	Y	Y	U	Y	Y	Y	Y	Y	Y
	Are suggestions provided for further areas to research?	N	Y	Y	Y	Y	Y	N	N	Y	Y
	Is there external validity?	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y

Calculation for section validity: (Y+N+U = T) If Y/T <75% or if N+U/T > 25% then you can safely conclude that the section identifies significant omissions, and that the study's validity is questionable. It is important to look at the overall validity as well as section validity.	**Calculation for overall validity: (Y+N+U = T)** If Y/T ≥75% or if N+U/T ≤ 25% then you can safely conclude that the study is valid.
Section A validity calculation: 1/4 = 25% not valid **Section B validity calculation: 5/7 = 71% not valid** **Section C validity calculation: 1/5 = 20% not valid** **Section D validity calculation: 4/6 = 67% not valid**	**Overall validity calculation:** **11/22 = 50% not valid**

Y: Yes; N: No; U: unclear; N/A: Not Applicable