The impact of uncorrected refractive error on children: A systematic review

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ABSTRACT

Background: The recognition of uncorrected refractive error (URE) as the major cause of vision impairment globally, particularly in children, has highlighted the need for evidence that can inform policy, service delivery and research. A systematic review that addresses these issues in children will add to the much needed body of evidence.

Objectives: To summarise relevant evidence investigating the impact of URE on children and the impact of correcting refractive error on children.

Design: Systematic review.

Participants: Children (5-18 years) and undergraduate students (18-21 years) globally.

Methods: We systematically searched 13 databases and the reference lists of retrieved studies. The methodology employed adhered to the PRISMA statement. Assessment of the quality of full text articles for inclusion in the review synthesis applied the use of the Consolidated Standards of Reporting Trials (CONSORT) Guidelines and the Critical Appraisal Skills Programme (CASP) tools. As the studies were anticipated to be heterogenous a meta-analysis was not planned. The findings of the review are reported using descriptive narrative.

Main Outcome Measures: Quality of life (visual functioning, well-being, headaches and risk of accidents), psychosocial impact (sleep disorder and self-esteem), educational (literacy, reading ability and academic performance), and negative impacts (teasing and bullying or discrimination)**.**

Results: The search retrieved 6007 studies of which 21 met the inclusion criteria. Of the 21 studies selected for inclusion in the review, two were randomised control trials (RCTs), four were cohort studies, one had a case control design, two were qualitative studies, 15 studies employed a cross-sectional design and one was an ecological study. Five studies included more than one design type.

Conclusions: While numerous studies have been published on the prevalence of refractive errors there is a dearth of high quality studies measuring the impact of URE on children or the impact of spectacle correction. Given the complexity of measuring the impact on academic achievement due to the multifactorial nature of possible influences, rigorous well-designed RCTs are needed.

INTRODUCTION

Refractive errors result from disorders of the eye's ability to focus light on the retina, leading to an unfocussed view of the world. This is a leading cause of visual impairment (visual acuity <6/18) amongst children, worldwide, it is estimated to affect more than 12 million children aged between 5 and 15 years, half of whom live in China [1]. The different types of refractive error that can affect children are short-sightedness (myopia) when distance vision is out of focus, long-sightedness (hyperopia) when clear near vision is difficult, and/or astigmatism (irregular corneal curvature) when distance and near vision are distorted [2] . Refractive errors in children are easily correctable, usually by a pair of spectacles [3] however studies conducted in children at eight locations in Asia, Africa and South America suggests that 10% of children in the low and middle income settings are in need of refractive correction, with Asia having a much higher proportion of the cases [4-11]. Spectacles remain the most popular method of RE correction in children, particularly in low resource settings [7, 12-16] as it is non-invasive and inexpensive [17]. However many children do not have access to a pair of spectacles or fail to wear them (even when provided for free) - thus any positive impact of spectacle correction is not being attained in many populations [17].

In a review of multiple studies, the study [18] concluded that the development of refractive errors is influenced by both environmental and behavioural risks factors such as education [2,19], socio-economic status [20], reading/near work/ studying habits [21,22], intelligence [22], urbanisation [8, 10, 23], outdoor activity [24-26], occupation [27] and genetic factors [28-33]. There is an increasing body of evidence that myopia is associated with higher intelligence and hyperopia with lower than normal intelligence which may be due to genetic factors [34]. These findings have implications for

studies which aim to assess the impact of uncorrected refractive errors (URE) on educational outcomes as well as the impact of correcting refractive errors in children.

It has been suggested that clear and comfortable vision is critical to ensure the ability of children to learn. Many authors have suggested a correlation between refractive errors (particularly undetected and untreated) and lower levels of reading and difficulties in reading among children who have already learnt to read [35-37]. Furthermore, vision problems in children may also cause developmental difficulties and have been linked to anti-social behavior [38, 39]. However, it is not clear whether these associations are causal.

To the best of our knowledge, no systematic review or meta-analysis of the impact of URE on children has been published, or registered, to date. We set out to extract published data that investigates the impact of URE on children and synthesize the findings in a systematic method. In addition, we investigated the evidence available on the short and long term impact of correcting refractive errors on children. Thus the aim of this systematic review was to evaluate scientific and published research studies on the impact of refractive error on a child's life-long health, school performance and emotional/social development, and to review the impact of correcting refractive errors. Children aged less than five years were excluded, as this is a period of rapid eye growth and change in refractive status. Assessing visual acuity in young children is also challenging, and many of the potential outcomes of correcting URE, such as visual function, cannot be assessed. There is also some evidence that the apparent association between hyperopia and poor pre-literacy skills in this age group may not be causal, but as the result of common ecological pathways [40].

METHODS

The systematic review followed the reporting items for systematic reviews as described in the PRISMA statement [41].

Eligibility Criteria

The population of interest was children (aged 5-18 years) and undergraduate students (aged 18-21 years) globally. Interventions of interest were refractive error correction using spectacles or contact lenses. The outcomes included quality of life (functional vision, well-being, headaches and risk of accidents), psychosocial factors (sleep disorder and self- esteem), economic outcomes (cost of illness) and educational outcomes (learning, reading, school attendance and academic performance). We also included studies that reported teasing, bullying and/or discrimination among children given spectacles. Studies with the following designs were included: individual or cluster randomised control trials (RCTs), observational cross-sectional studies, cohort studies (prospective and retrospective) and ecological and qualitative studies. We considered articles published from January 1994 to May 2015 without language limits.

Information Sources and Search Strategy

The search strategy was devised by an Information Specialist (Iris Gordon) who developed a set of terms with filters to exclude studies not of interest (e.g. laboratory studies). A sample of the records removed by the filter was reviewed to ensure that no potentially relevant records were being discarded. The following databases were searched: MEDLINE, PubMed, EMBASE, the Cochrane Library, CINAHL, Global Health, PsychINFO, ERIC, Web of Science (SCI, SSCI, A&HCI, CPCI-S, CPCI-SSH), Open Grey, New York Academy of Medicine Grey Literature Report, Clinicialtrials.gov, the World Health Organization (WHO) International Clinical Trials Registry Platform (ICTRP). Databases were searched from April – June 2015. See appendix 1 for details of search strategies used.

Study Selection

Citations from the search were imported from the bibliographic databases into EndNote for screening for eligibility. The Information Specialist pre-screened the results to remove duplicates and records which were not relevant to the scope of the review and forwarded the results (EndNote abstract files) to two reviewers who independently screened the remaining title and abstracts. Full text was obtained of retained studies. Three independent reviewers (Kovin Naidoo, Jyoti Naidoo and Clare

Gilbert) then critically appraised the full text to determine whether they met the systematic review inclusion criteria.

Qualitative Assessment and Data Extraction

Critical Appraisal Skills Programme (CASP) tools [42, 43] were used to assess the quality of the full text articles for inclusion in the review. The CASP tools were designed to aid assessment of the reporting of systematic reviews and clinical trials, to determine whether qualitative research was reliable or not, and to assess economic papers and opinion articles. The quality appraisal checklist derived from CASP was used in this review [43]. We modified the critical appraisal tools and checklists (CASP tools) available for different study designs (cross-sectional, quantitative, cohort and others) to suit our research question by creating one tool that could be used across all study designs. The final tool consisted of 15 questions and the answers for each were graded between 0 and 2 (Appendix 2). Two reviewers (Kovin Naidoo and Nyika Mtemeri) compared their quality appraisal scores and confirmed the scores through consensus. The Consolidated Standards of Reporting Trials (CONSORT) [44] tool, consisting of 25 sections, was used to appraise the quality of reporting RCTs.

Data were then extracted from each of the studies included in the review and entered into an excel spreadsheet designed by the authors. Extracted information included: first author, year of publication, title, country in which the study was performed, study design, sample size, type of refractive error, refractive error correction, main outcome measures and study findings, conclusions and limitations. The quality of the evidence was graded as low, moderate or high. Data were extracted independently by three reviewers and disagreements were resolved through discussion.

Assessment of Risk

Risk of bias was assessed using the Cochrane Handbook for Systematic Reviews of Intervention [45] as the recommended tool. Different ways of categorising were incorporated which include;

randomisation sequence generation, allocation concealment, blinding of participants, detection bias, incompleteness bias, reporting bias and other sources of bias should there be any.

Synthesis of results and assessment of robustness

As the studies were expected to be heterogeneous in terms of setting, intervention, study design and the outcomes measured - a single effectiveness summary statistics across studies was not planned. A narrative descriptive analysis of study results is reported for each of the outcomes of interest. The review was conducted and presented in 4 main categories: 1) Studies that were selected and the screening process, 2) Characteristics of the studies and exploring their relationships, 3) Quality assessment of studies as it was applied from CASP and CONSORT, and 4) Synthesis of results on different impact factors.

RESULTS

Study selection

The search yielded a total of 6007 records, of which two studies were identified through hand searching and no studies were identified from the grey literature. 2145 duplicates were removed and the Information Specialist (IS) pre-screened 3862 records and removed 2780 which were not relevant to the scope of the review. The reviewers screened the remaining 1082 records and discarded a further 999 records as not meeting the inclusion criteria. A total of 83 full text reports were obtained for further assessment. After reading the full text articles, 21 met the inclusion criteria and 62 articles were excluded, with reasons, as they were not relevant to the objectives of the review (Figure 1).

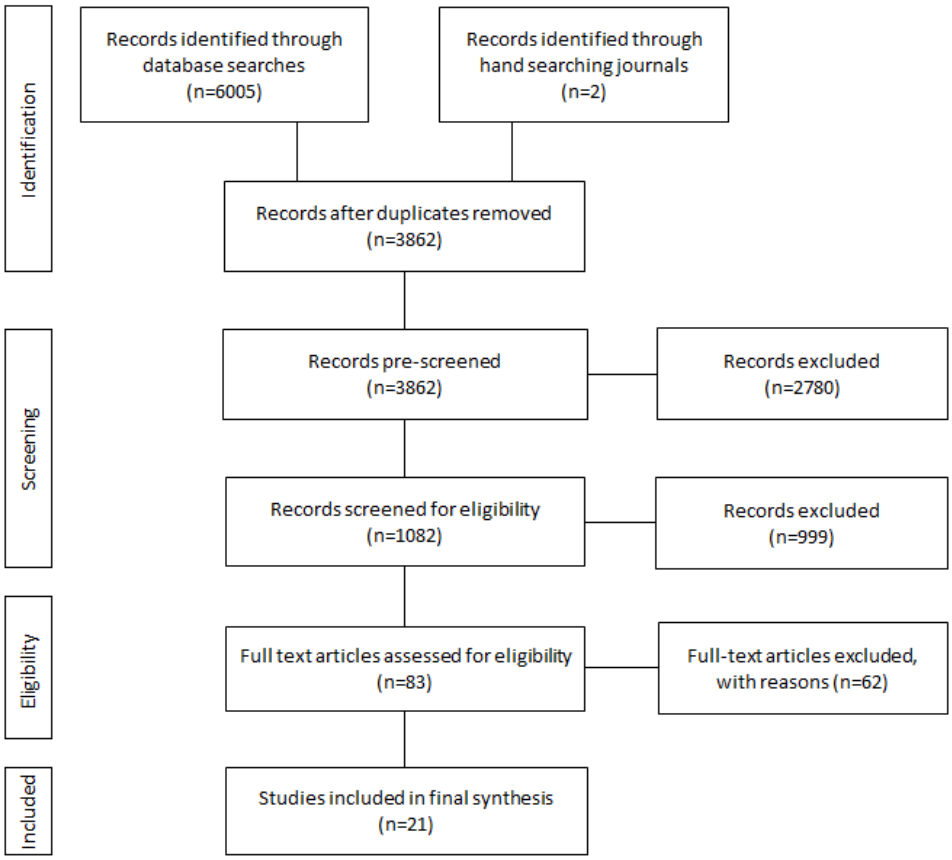

Figure 1. Flow diagram showing the selection process for inclusion of studies in the systematic review

Study characteristics

The main characteristics of the final 21 selected studies are included in Table 1. Of the 21 selected studies, two were RCTs [46, 47], four were cohort studies [14, 23, 26, 48], one study included a case control [37], two studies were qualitative [49, 50] and 16 studies were cross-sectional [17, 20-23, 35-37, 46, 49-55]. One study was ecological [56]. Table 2 indicates that five studies [23, 37, 46, 49, and 50] included more than one design type. The Odedra study [49] was a cross-sectional and qualitative study of children given spectacles which was embedded within a cluster RCT. Hannum et al. [46] included two separate studies (an RCT and an observation cross-sectional study).

Table 2: Study designs and impact measurement

Design	**Quality of life** (visual functioning, well-being, headaches, risk of accidents) (10)	**Psychosocial impact** (sleep, self-esteem)(3)	**Educational** (literacy, reading, academic performance) (15)	**Impact on correction** (Academic, teasing and bullying, discrimination, loss of self-esteem) (7)
Cluster randomized control trial (2)			Ma [47] (Sp) Hannum [46] (Sp)	Hannum [46] (Sp) Ma [47] (Sp)
Cohort study (4)	Zhang [23]; Esteso [14]) (Sp)		Krumholtz [48] (Sp); Dirani [26]	]; Esteso [14]) (Sp)
Before and after study (5)	Esteso [14] (Sp)	Odedra [49] (Sp)	Hannum [46] (Sp) Ma [47] Krumholtz [48]	Hannum [46] (Sp) Ma [47]
Case control study (1)			Dusek [37]	
Qualitative study (2)	Kumaran [50]	Odedra [49] (Sp)		Odedra [49] (Sp) Kumaran [50]
Cross-sectional (16)	Wong [26] Kumaran [50] Dusek [37] Hendricks [52] Shashidhar [53] Mutti [21]	Zhou [55](2015) Dias [51] (Sp) Odedra [49] (Sp)	Rosner [35] Dias [51] (Sp) Shashidhar [53]) Zhang [23] Basu [54]	Williams [36] (Sp) Dias [51] (Sp)

	Congdon [17]		Saw [22] Williams [36] (Sp) Mutti [21] Congdon [17] Hannum [46]	
Ecological study (1)	Morgan [56]		Morgan [56]	

Sp = spectacles used for correction; CL – contact lenses used for correction

Six of the 21 studies were conducted in China [17, 23, 46, 47, 55, 56], 4 in the USA [21, 35, 48, 51], 3 in Singapore [20, 22, 26], 3 in India [50, 53, 54], 1 respectively from Tanzania [49], Austria [37], Netherlands [52], Wales [36] and Mexico [14]. Sample sizes of the study populations ranged from 27 children included in the cross-sectional study [50] to 3052 students in the school performance RCT [47].

Among the 21 studies included in the review, six studies used random sampling techniques [17, 23, 35, 47, 49, 54]. The remaining studies used non-random sampling methods. Studies examined the following impact issues (Table 3):

Table 3: Impact issues identified in the included papers

Impact	Article
Educational (15)	
impaired literacy (1)	Williams [36]
reading difficulties (1)	Dusek [37]
academic performance (13)	Congdon [17]; Mutti [21]; Saw [22]; Zhang [23]; Dirani [26]; Rosner and Rosner [35]; Hannum [46]; Ma [47]; Krumholtz [48]; Dias [51]; Shashidhar [53]; Basu [54]; Morgan [56]
Quality of Life (10)	
general quality of life (5)	Wong [20]; Dusek [37]; Kumaran [50]; Shashidhar [53]; Morgan [56]
visual functioning (3)	Esteso [14]; Congdon [17] ; Mutti [21]
well-being (headaches) (1)	Hendricks [52]
Accidents (1)	Zhang [23]
Psychosocial (3)	
sleep disorder (1)	Zhou [55]
self-esteem (2)	Odedra [49]; Dias [51];
RE Correction (positive impacts)	
Academic (4)	Esteso [14]; Hannum [46]; Ma [47]; Dias [51]
Appearance (1)	Odedra [49]
Self-esteem (1)	Dias [51]
RE Correction (negative impacts)	
Academic (3)	Williams [36]; Hannum [46]; Kumaran [50]
Teasing and bulling(1)	Odedra [49]

Key outcome measures, study results and conclusions are presented in Table 1.

Quality assessment

Application of CASP and CONSORT (Table 4) tools identified some general limitations in the studies. While all the cross-sectional studies applied rigour in the selection of appropriate samples, the measurement of impact was open to confounding, as it is difficult to control for other factors, when measuring academic performance or other impact factors without a control group. Of all the studies which had interventions, only five [14, 46-49] had the outcome of interest measured before and after children were given either spectacles or contact lenses. Most of the studies provided details of the sampling frame and the sampling method used except for two studies [14, 37]. Only two studies reported sample size calculations, one being a randomized trial [47] and the other being a cross-sectional study [54]. All studies had a good sample size except one [50] which had a sample size of 27. The study was however included in the review because it was a qualitative study [50]. Only 3 of the 21 studies clearly outlined the methodology for managing missing data [23, 46, 47] in the data analysis.

Table 4. CONSORT

Title and abstract	**Author(s)**	**Hannum et al. [46]**	**Ma et al. [47]**
	Year of Publication	2008	2014
	Country	China (5)	China (2)
	Title of paper	Poverty and Proximate Barriers to Learning: Vision Deficiencies, Vision Correction and Educational Outcomes in rural Northwest China. (1)	Effect of providing free glasses on children's educational outcomes in China: cluster randomized control trial. (1)
	Abstract	Appendix 3	Appendix 3

Introduction	**Background**	Few studies of educational barriers in developing countries have investigated the role of children's vision problems. (5)	Children with uncorrected refractive errors have lower scores on a variety of motor and cognitive tests, and that improvements in reading may occur when vision problems are corrected. (2)
	Purpose	Investigate whether vision correction matters for educational outcomes - performance on standardized achievement tests and class failure.	To determine if education promoting the wearing of glasses aimed at school children will improve children's glasses wear and improve their academic performance.
	Interventions	Glasses.	Glasses.
	Outcomes	There is a relationship between vision correctness and educational outcomes. (24)	Effect of free glasses on academic performance. (4)
	Outcome Measures	Educational outcomes.	Academic performance.
	Sample Size	19185 (11)	3052(1)
	Sequence generation	Multi-stage sampling (2)	Multi-stage sampling (2)
	Allocation of concealment mechanism	Random (16)	Random (2)
	Impementation	Centre for Disease Control personnel. (11)	Author and the team. (5)
	Blinding	Not stated.	Participants (students, parents and teachers) and enumerators. (3)

	Method of analysis	Descriptive statistics, Cronbach's alpha test, logistic regression, multivariate analysis. (17, 20)	Regression, imputations for missing data, correlation. (3, 4)
	Sampling Methodology	Randomization - some townships were given treatment and others served as controls. (11)	Sample size of 252 school with a minimum of 10 students ; 84 schools allocated to the free glasses group; 84 allocated to the voucher group; 84 were allocated to the control group. (3,4)
Results	**Participant flow**	Appendix 4	Appendix 4
	Recriutment	2000, 2004. (1)	2012-2013. (1)
	Baseline data	Appendix 5	Appendix 5
	Numbers analysed	18817 (11)	3052 (12)
	Outcome and estimation	The GVIP findings suggest that there is an elevated chance of poor eyesight among children who perform well, among children who are older and who are girls, and among higher socioeconomic status children, as indicated by non-farm family status. (19)	The difference between groups was smaller than what the study was powered to detect. The observed effect size of 0.11 SD was the equivalent of approximately half a semester of additional learning. (4)

	Ancillary analyses	Although the GVIP and GSCF suggest different measures, neither suggests that the most socioeconomically deprived are at particularly high risk of poor eyesight. Scrutinizes of both datasets suggest that there is a propensity for vision problems to be greater among higher socio-economic status children and among children who are more educationally involved. (19)	No interaction was found between the glasses and education. (4)
	Harms		Data for imputations was not shown. (4)
Discussion	**Limitations**	Does not provide information on whether masking was done or not. Those who are more motivated are the ones accepting glasses in the GVIP and the sources of selectivity will ultimately impact on the results of the study. It is not clear how schools were randomized; whether the schools were	Highly complex with multiple subgroups. No explanation was given on how the maths score was delivered and how to improve it. The use of only a single mathematics test as an outcome measure capturing educational performance is questionable since this is mainly applicable for classroom learning. All schools where in rural north-west of China, which is a limitation with reference to other population setups.

		masked or to which arm of the trial they were in. There is no evidence that the strategy for matching the treatment and control samples had fully accounted for pertinent differences in unmeasured variables a point the authors acknowledge.	Masking was not practical. Compliance with glasses was less than optimal and could not be accurately evaluated by self-report. The effect size was biased due to the groups enrolled (children with poor vision in only one eye and those already wearing spectacles were included - this could have skewed the results). (4-5)
	Generalisability	A very small percentage of children wore glasses yet vision difficulties are selective of better-off children and more scholastically involved students, and this discernment makes isolation the causal impact of glasses-wearing a difficult task. (25)	As a result of this study, pilot programs were started in Shaanxi and Gansu Provinces in providing free glasses to children. (5)
	Interpretation	Poor eyesight impedes children educational experience; common sense notion that correcting vision supports learning. (19, 24, 25)	The effect size on education outcomes with the provision of glasses in this study compares favourably with other health related interventions. (5)
Other	**Registration**	None.	Registered but information not provided. (5)

	Prorocol	Not provided.	Not provided.
	Funding	Not stated.	One Sight (Mason OH), Luxottica - China (Shanghai), ESSILOR-China (Shanghai), CLSA (Asia Pacific Markets; Hong Kong), Charity Aid Foundation (Sydney), and anonymous donor (Hong Kong). (5)

Risk of Bias

Allocation (Selection Bias). Two studies were randomised control trials [46, 47]. In these two studies, allocation concealment was not mentioned in detail, which can lead to a greater risk of bias. Five studies [17, 23, 46, 47, 54] were classified as low risk since the selection and allocation method used was random (Table 5). In one study [49], selection of participants was non-random but schools were randomly allocated. This study was neither classified as high or low risk. All other studies used non-random method of selection and allocation and were classified as high risk.

Blinding (Performance Bias and Detection Bias). In the study by Ma *et al.* [47], participants (students, parents and teachers) and enumerators were blinded in the overall design of the study but the study did not clearly detail how the blinding was done. This study was classified as low risk of bias even though the process of blinding was not given in detail. Most of the other studies were unclear on blinding of the participants and also of the assessors and were neither classified as high risk nor low risk.

Incomplete outcome data. In the study by Ma *et al.* [47], among the 123 missing children, 26 (21%) were at home the day of follow up, 90 (73%) had moved to a different school and seven (6%) had withdrawn from school. This was classified as low risk due to the information given on missing information. Basu *et al.* [54] reported a non-participation of 3.25% which was mainly due to absents and refusals. No other details were stated on the missing information. Hendricks *et al.* [52] had high response rate even though the non-participation mainly was due to illness (6%), no permission from

parents (5%) and spoiled questionnaires (6%). This was classified as low risk. Zhou *et al.* [55] in their study mentioned that they did not get feedback from the parents in about 3.5% of the participants though it was not so clear on the reasons. For this reason, this was classified as low risk. In a different study by Hannum *et al.* [46]), two different groups were considered where on follow up, 13% was missing for GSCF group and 368 for GVIP group. For both groups, no reason for missing information on the follow ups was given in this study. This was classified as low risk even though not much information was given on the missing data. Most of the studies were unclear since they did not provide details on the missing data.

Selective reporting (Reporting Bias). Result from the final study should always be compared to what has been proposed in the protocol. Among all the studies considered, no protocol could be found even though two of the RCT studies declared the registration numbers. The risk of reporting bias among all these studies was classified as unclear.

Other potential Source of bias. No other sources of bias were identified.

Table 5. Reason for risk of bias

Study	Risk of bias		Reasons for the risk of assessment
Esteso [14]	Random sequence generation	H	Authors' description of sampling does not clearly suggest a random selection of the participants.
	Allocation concealment	U	Allocation concealment was not sufficient to protect against bias.
	Participants blinding	U	No information on blinding was mentioned.
	Assessor blinding	U	No information on blinding was mentioned.
	Incomplete outcome data	U	Insufficient reporting of attrition/exclusions to permit judgment of 'Low risk' or 'High risk'.
	Selective outcome reporting	U	Protocol for the study is not available and it is uncertain whether the published reports comprises of all anticipated outcomes.
Congdon [17]	Random sequence generation	L	Randomization and allocation methods were used for allocation of schools. No clear randomization was mentioned in children.
	Allocation concealment	U	No allocation concealment was mentioned.

	Participants blinding	U	Masking of participant was not clear
	Assessor blinding	U	No information provided.
	Incomplete outcome data	U	Insufficient reporting of attrition/exclusions to permit judgment of ‘Low risk’ or ‘High risk’.
	Selective outcome reporting	U	Protocol for the study is not available and it is uncertain whether the published reports comprises of all anticipated outcomes.
Wong [20]	Random sequence generation	H	Authors described the allocation and selection of participants as entirely nonrandom
	Allocation concealment	U	Allocation concealment was not mentioned.
	Participants blinding	U	Blinding of participants not mentioned.
	Assessor blinding	U	No blinding of assessor was stated I the study.
	Incomplete outcome data	U	Insufficient reporting of attrition/exclusions to permit judgment of ‘Low risk’ or ‘High risk’.
	Selective outcome reporting	U	Protocol for the study is not available and it is uncertain whether the published reports comprises of all anticipated outcomes.
Mutti [21]	Random sequence generation	U	Selection of children was not clearly random
	Allocation concealment	U	Allocation was not adequately concealed.
	Participants blinding	U	Participants blinding was not mentioned.
	Assessor blinding	U	No information provided.
	Incomplete outcome data	U	Report based on only 125 of 190 children who were myopic and completed self-concept measurements.
	Selective outcome reporting	U	Protocol for the study is not available and it is uncertain whether the published reports comprises of all anticipated outcomes.
Saw [22]	Random sequence generation	H	Randomization and allocation techniques were not mentioned in detail.
	Allocation concealment	U	Allocation concealment was not mentioned.
	Participants blinding	U	Participation blinding was not clear.

	Assessor blinding	U	No blinding for assessor was mentioned.
	Incomplete outcome data	U	Insufficient reporting of attrition/exclusions to permit judgment of ‘Low risk’ or ‘High risk’.
	Selective outcome reporting	U	Protocol for the study is not available and it is uncertain whether the published reports comprises of all anticipated outcomes.
Zhang [23]	Random sequence generation	L	A random method was sued for selection and allocation of participants with VA better than 6/12 in both eyes.
	Allocation concealment	U	Allocation concealment was not mentioned.
	Participants blinding	U	Blinding of participants not stated
	Assessor blinding	U	No information provided.
	Incomplete outcome data	U	Insufficient reporting of attrition/exclusions to permit judgment of ‘Low risk’ or ‘High risk’.
	Selective outcome reporting	U	Protocol for the study is not available and it is uncertain whether the published reports comprises of all anticipated outcomes.
Dirani [26]	Random sequence generation	U	Random selection of children was not clear
	Allocation concealment	U	Allocation was not adequately concealed.
	Participants blinding	U	Participants blinding was not mentioned.
	Assessor blinding	U	No information provided.
	Incomplete outcome data	U	Insufficient reporting of attrition/exclusions to permit judgment of ‘Low risk’ or ‘High risk’.
	Selective outcome reporting	U	Protocol for the study is not available and it is uncertain whether the published reports comprises of all anticipated outcomes.
Rosner and Rosner [35]	Random sequence generation	H	Randomization and allocation techniques were applied in this study.
	Allocation concealment	U	Allocation was not adequately concealed.

	Participants blinding	U	Participants blinding was not mentioned.
	Assessor blinding	U	No information provided.
	Incomplete outcome data	U	Insufficient reporting of attrition/exclusions to permit judgment of ‘Low risk’ or ‘High risk’.
	Selective outcome reporting	U	Protocol for the study is not available and it is uncertain whether the published reports comprises of all anticipated outcomes.
Williams [36]	Random sequence generation	H	The method of allocating participants was not truly random.
	Allocation concealment	U	Allocation was not adequately concealed
	Participants blinding	U	Participants blinding was not mentioned
	Assessor blinding	U	No information provided.
	Incomplete outcome data	U	Insufficient reporting of attrition/exclusions to permit judgment of ‘Low risk’ or ‘High risk’.
	Selective outcome reporting	U	Protocol for the study is not available and it is uncertain whether the published reports comprises of all anticipated outcomes.
Dusek [37]	Random sequence generation	H	The method of referring participants to the optometrist was not entirely random.
	Allocation concealment	U	Allocation was not adequately concealed.
	Participants blinding	U	Participants blinding was not mentioned.
	Assessor blinding	U	No information provided.
	Incomplete outcome data	U	Insufficient reporting of attrition/exclusions to permit judgment of ‘Low risk’ or ‘High risk’.
	Selective outcome reporting	U	Protocol for the study is not available and it is uncertain whether the published reports comprises of all anticipated outcomes.
Hannum [46]	Random sequence generation	L	Random method was used to select and to assign townships to receive treatment.
	Allocation concealment	U	Allocation concealment was not clear.
	Participants blinding	U	Blinding of the participants was not mentioned.

	Assessor blinding	U	No information provided.
	Incomplete outcome data	L	1918 participants were followed up and 13% were not in school. In the other set, 165 out of 19 185 were eliminated.
	Selective outcome reporting	U	Protocol for the study is not available and it is uncertain whether the published reports comprises of all anticipated outcomes.
Hannum [46]		H	Method of randomization and allocation was not mentioned in detail.
		U	Allocation concealment was not mentioned.
		U	Participants blinding was not mentioned
		U	No information provided.
		U	Insufficient reporting of attrition/exclusions to permit judgment of 'Low risk' or 'High risk'.
		U	Protocol for the study is not available and it is uncertain whether the published reports comprises of all anticipated outcomes.
Ma [47]	Random sequence generation	L	Participants were randomly selected form each township in the sample and randomly selected for allocation of the intervention.
	Allocation concealment	U	Allocation concealment was not mentioned.
	Participants blinding	L	Participants (students, teachers and parents) were blinded.
	Assessor blinding	L	Outcome enumerators were blinded
	Incomplete outcome data	U	No information provided small number of participants in the study to permit decision of 'Low risk' or 'High risk'.
	Selective outcome reporting	U	Protocol for the study is not available and it is uncertain whether the published reports comprises of all anticipated outcomes.
Krumholtz [48]	Random sequence generation	H	Author's description of sampling does not clearly suggest a random selection of the participants.
	Allocation concealment	U	Allocation was not adequately concealed
	Participants blinding	U	Participants blinding was not mentioned

	Assessor blinding	U	No information provided.
	Incomplete outcome data	U	Insufficient reporting of attrition/exclusions to permit judgment of ‘Low risk’ or ‘High risk’.
	Selective outcome reporting	U	Protocol for the study is not available and it is uncertain whether the published reports comprises of all anticipated outcomes.
Odedra [49]	Random sequence generation	U	Non-random is selection of participants but randomly allocated schools.
	Allocation concealment	U	Allocation concealment was not mentioned.
	Participants blinding	U	Blinding of participants was not clearly stated.
	Assessor blinding	U	No information provided.
	Incomplete outcome data	U	Insufficient reporting of attrition/exclusions to permit judgment of ‘Low risk’ or ‘High risk’.
	Selective outcome reporting	U	Protocol for the study is not available and it is uncertain whether the published reports comprises of all anticipated outcomes.
Kumaran [50]	Random sequence generation	H	Authors’ description of sampling does not clearly suggest a random selection of the participants.
	Allocation concealment	U	Allocation concealment was not mentioned.
	Participants blinding	U	Blinding of participants was not mentioned.
	Assessor blinding	U	Blinding of optometrists and ophthalmologists was not mentioned.
	Incomplete outcome data	U	No information provided small number of participants in the study to permit decision of ‘Low risk’ or ‘High risk’.
	Selective outcome reporting	U	Protocol for the study is not available and it is uncertain whether the published reports comprises of all anticipated outcomes.
Dias [51]	Random sequence generation	H	The selection and allocation method was not clearly categorized.
	Allocation concealment	U	Allocation concealment was not mentioned.
	Participants blinding	U	No information provided.
	Assessor blinding	U	No information provided.

	Incomplete outcome data	U	Insufficient reporting of attrition/exclusions to permit judgment of ‘Low risk’ or ‘High risk’.
	Selective outcome reporting	U	Protocol for the study is not available and it is uncertain whether the published reports comprises of all anticipated outcomes.
Hendricks [52]	Random sequence generation	H	Technique of randomization and allocation was not mentioned in detail.
	Allocation concealment	U	Allocation concealment was not mentioned.
	Participants blinding	U	Blinding of school children was not mentioned.
	Assessor blinding	U	No information provided on blinding of school teachers.
	Incomplete outcome data	L	Nonparticipation was due to illness (6%), no permission from parents (5%) and spoiled questionnaires (6%).
	Selective outcome reporting	U	Protocol for the study is not available and it is uncertain whether the published reports comprises of all anticipated outcomes.
Shashidhar [53]	Random sequence generation	H	Method of randomization and allocation was not mentioned in detail.
	Allocation concealment	U	Allocation concealment was not mentioned.
	Participants blinding	U	Participants blinding was not mentioned
	Assessor blinding	U	No information provided.
	Incomplete outcome data	U	Insufficient reporting of attrition/exclusions to permit judgment of ‘Low risk’ or ‘High risk’.
	Selective outcome reporting	U	Protocol for the study is not available and it is uncertain whether the published reports comprises of all anticipated outcomes.
Basu [54]	Random sequence generation	L	Randomization and allocation methods were used for allocation of schools and participants.
	Allocation concealment	U	No allocation concealment was mentioned.
	Participants blinding	U	No information on blinding was mentioned.
	Assessor blinding	U	No information provided.

	Incomplete outcome data	L	Non-response (3.25%) was due to absents and refusals. The main outcome measures were analyzed on 3002 participants.
	Selective outcome reporting	U	Protocol for the study is not available and it is uncertain whether the published reports comprises of all anticipated outcomes.
Zhou [55]	Random sequence generation	H	Method of randomization and allocation was not mentioned in detail.
	Allocation concealment	U	Allocation concealment was not mentioned.
	Participants blinding	U	Participants blinding was not mentioned
	Assessor blinding	U	No information provided.
	Incomplete outcome data	L	Non-participants included children with questionnaires not returned by their parents (3.5%)
	Selective outcome reporting	U	Protocol for the study is not available and it is uncertain whether the published reports comprises of all anticipated outcomes.
Morgan [56]	Random sequence generation	H	Randomization and allocation techniques were not mentioned in detail.
	Allocation concealment	U	Allocation concealment was not mentioned.
	Participants blinding	U	Participants blinding was not mentioned.
	Assessor blinding	U	No evidence provided.
	Incomplete outcome data	U	Insufficient reporting of attrition/exclusions to permit judgment of ‘Low risk’ or ‘High risk’.
	Selective outcome reporting	U	Protocol for the study is not available and it is uncertain whether the published reports comprises of all anticipated outcomes.

Synthesis of results

The findings are reported under the following headings: 1) educational outcomes (impaired literacy, reading difficulties and academic performance), 2) psychosocial (sleep disorder and self-esteem) and 3) quality of life, (visual functioning, well-being, headaches and risk of accidents). Negative outcomes

following refractive correction included academic, teasing and bullying whilst the positive outcomes included academic, appearance and self-esteem.

1) Educational outcomes

Of the fifteen studies that addressed educational performance, 10 were cross-sectional studies [17, 21-23, 35, 36, 46, 51, 53, 54], 2 were cohort studies [26, 48], 2 were RCT [46, 47], one study was a case control [37] and one was an ecological study [56].

- *Academic performance*

Two cluster randomized trials have assessed academic performance among school children with myopia in China [46, 47]. In one trial [47] the authors used mathematics test scores as the educational outcome of interest, arguing that these scores are often used in studies to assess education interventions as they are less influenced by the home environment, language and writing ability, for example. The trial reported that provision of free spectacles was associated with a statistically significant increase in mathematics scores despite relatively low compliance with spectacle wear. The mathematics test was designed for this trial, based on International Mathematics and Science Study, and the findings were presented using scores derived using the international norms for analysis. The change in maths scores were interpreted by the authors based on a previous study. However, the observed difference between groups was smaller than the study was originally designed to detect. Despite the population based sampling, RCT design, high participation and follow-up rates the study has limitations (refer to Table 4 for limitations) [57]. For example, the study design was highly complex, with a factorial design and multiple subgroups, and the authors acknowledge that masking of the both the allocation and assessment of the outcome was not practical. In this trial the authors used the visual acuity in either eye whereas impact assessment should use the better seeing eye as will better reflect a child's visual functioning and hence ability to learn.

The other study from China [46] included both a cohort study (longitudinal follow up of visually impaired children not randomized to spectacle correction) as well as a cluster randomized trial). The study found that those who received spectacles were less likely to fail a class and that there is a tendency for vision problems to be greater among higher socio-economic status children and amongst children who are more educationally engaged. It is important to consider the fact that this could merely mean that those who are more motivated are the ones accepting glasses in the GVIP and the sources of selectivity will ultimately impact on the results of the study. It is not clear how schools were randomized; and whether the schools were masked to which arm of the trial they were in. There is no evidence that the strategy for matching the treatment and control samples had fully accounted for pertinent differences in unmeasured variables a point the authors acknowledge. The authors however make a comparison with a previous experimental study by Glewwe, Park and Zhao [58] and indicate that since the RCT results are similar to the experimental study in that it shows significant effects of spectacle wearing on literacy and math scores; this is similar to the significantly positive effects for grades found in the experimental study. However, the assumption that similar means confirmation of a relationship is erroneous as the RCT could just be reinforcing the incorrect relationship that an experimental study may have established. The approach to the study was difficult to review due to the complex manner in which the results are reported and the challenges raised above prevent a firm conclusion being drawn from the data.

Furthermore, Rosner and Rosner [35], in the United States of America, examined the relationship between moderate hyperopia and academic achievement and found significantly lower achievement test scores among hyperopic children with a RE exceeding 1.25D ($p = 0.014$). When emmetropes are removed from the study, the difference between myopes and hyperopes is significant ($p=0.017$). The subjects were randomly chosen which strengthens the research design however there was no adjustment for confounding variables. A RCT would have been a more appropriate option to establish a link between hyperopia and academic achievement. The use of non-cycloplegic retinoscopy to determine the hyperopic correction also raises questions as to the accuracy of the refractive error measurement. The authors acknowledge that the study does not provide a cause-effect relationship between uncorrected hyperopia and school underachievement.

The study conducted by Shashidhar *et al*. [53], in India, investigated the scholastic performances of adolescents and concluded that scholastic performance decreased by 4.219 times (if a student has refractive error), by 3.623 times, (if the student receives no helps in his studies at home), by 5.235 times (if a student does not do his homework regularly), by 3.394 times (if a student does not answer question bank papers), by 3.802 times (if a student reads only before an examination). However the paper does not provide enough information as to how the children are recruited thus raising questions about the representativeness of the sample. In addition the analysis did not include an adjustment for confounders. Finally the tool used to determine scholastic performance is a local tool and there is no indication that it has been validated. This will call to question the measurement of improvement in scholastic performance.

Recognising the importance of confounders in determining the relationship between myopia and academic performance Saw *et al*. [22] investigated the relationship between school grades and myopia in Singapore. The odds ratio for myopia was 2.5 for children with average school examination scores in the fourth quartile compared with the first, after adjusting for confounders including reading in books per week and IQ scores. This study provides a good indication of a possible relationship between myopia and academic performance but unfortunately it used a cross-sectional study design and as a result determining causality is elusive due to inherent confounding in the design.

However Basu *et al*. [54] in investigating eye morbidities and scholastic performance among girls in India, found that amongst those with problems of eyesight, 75.93 % had good academic performance with the increase of the intensity of the educational load in terms of tutorial sessions and homework. This study did not use a standardised tool to measure academic achievement but depended on teachers reporting. Such a measure is unreliable as many other factors can influence the academic performance. There was also no assessment whether academic performance was influenced by type and severity of URE. This data should be considered in making any conclusions about the relationship between eye morbidities and scholastic performance.

The ecological study was undertaken to assess whether additional support in schools, in the form of tutorials and after class teaching, is associated with higher academic score (using data from standard international assessments) and a higher prevalence of myopia (using population based survey data) [56]. Data were analysed from 65 locations in 64 countries. The study showed that the prevalence of myopia was high in some of the locations in the highest quartile of academic scores, such as Shanghai-China, Hong Kong-China, Taiwan, Singapore, Japan and South Korea, but low prevalence countries also achieved high academic scores, such as Australia and Finland. However, this is an ecological study and so it is not possible to determine whether those with the outcome of interest (myopia) were exposed to the exposure of interest (extra tutorials or coaching), and confounders could not be controlled for.

A baseline, evaluation of self-esteem and the corresponding relationship with different ocular and demographic characteristics was considered by Dias *et al.*[51] with children participating in Correction of Myopia Evaluation Trial (COMET), on comparison of additional lenses and single vision lenses. The COMET group received eyeglasses (single vision lenses or progressive addition lenses depending on their randomized lens assignment) and were formally enrolled in COMET. Among other variables of concern, scholastic competence was compared between COMET children and the normative sample. COMET boys scored higher than normative ($P = 0.05$) and in a different slant of comparison, Asian and mixed children scored higher than Hispanic children in scholastic competence ($P < 0.01$).

Zhang *et al.* [23] investigated the effect of myopia and eyeglass wear on one of the daily activities among Chinese students pondering on bicycle riding, and the related injuries. A significant number of students who reported that they had refraction were involved in accidents and as a result requiring them to miss school for a period of time. Results from the multivariate analysis indicated that wearing spectacles at the time of examination was associated with bicycle accidents with odd ratio of 1.38 (1.02 – 1.86) and statistically significant ($P= 0.04$). The results of this study are based on a Chinese rural set up and the application to other studies must be treated with cautious.

Krumholtz [48] investigated the relationship on vision screening and academic performance on paediatrics attending grades K to 6 in a follow up period of two years. Of the children examined, a significant correlation between both test and the hyperopia assessment screening (P=0.47) was reported, indicating from the study that children with uncorrected refractive errors perform poorer academically. The results of this study cannot be generalized as there was no control and a small number of children were used in this study.

Dirani *et al.* [26] considered a Singapore Cohort Study of the Risk Factors for Myopia (SCORM) longitudinal study. In this study, school children between 9 to 10 years of ages were included however excluding those with any known ocular pathology. Measure of outcome was the grade 4 average mark, which was a nation-wide standard examination. The impact of academic performance was assessed on different levels of VA stability. Comparisons were based on the improvement of academic performance from grade three to four against the corresponding VA. The analysis of the results indicated that distance VA did not play a significant role in predicting academic school performance ($P< 0.05$).

A study on parental and heredity myopia was conducted by Mutti *et al.* [21]. In this study, amongst other measures of outcomes, level of school achievement was based on the test of basic skills. It was concluded from this study that children with myopia are likely to have parents with myopia. Time spent studying was also more likely to be high when it comes to children with myopia for them to score high tests results. The results from the analysis indicated that there was a relationship between education outcomes (significantly more time spent studying, more time on reading, less time on playing sports and higher score on Iowa Tests of Basic Skills) ($p<0.024$). In this regards, heredity was the most important factor associated with juvenile myopia.

The study conducted on rural school children from China showed a significant impact on self-reported visual function. In this study, Congdon *et al.* [17] indicated that 10 academic subjects were selected as a measurement for all the children in the sample study. From this study, a significant number of children reported that they were wearing spectacles at the time of examination. Among

these children, some of them indicated that their more-educated parent had completed high school. Some of the children with visual disability had no proper correction, and ultimately they reported a worse visual acuity, which could have an impact on academic subjects. The group of children that was undergoing refraction had more myopic refractive error associated with self-reported visual function ($P<0.05$)

- *Reading difficulties*

In a retrospective, facility based study, Dusek *et al*. [37] set out to investigate the prevalence of refractive errors and binocular vision anomalies and reading ability in cases vs. controls in Australia. Statistical analysis using one way ANOVA demonstrated no differences between the two groups in terms of refractive error and the size or direction of heterophoria at distance ($p > 0.05$) (Dusek *et al*., [37]. However, those with a slower reading speed, than the control group, were statistically more likely to have a poorer distance visual acuity, an exophoric deviation at near, a lower amplitude of accommodation, reduced accommodative facility, reduced vergence facility, a reduced near point of convergence, a lower AC/A ratio. Thus, the study highlighted the importance of binocular visual status in reading. The sample selection is non-random as patients are referred to an optometry practice which limits the generalisability of these findings. Furthermore, this study does not control for confounding variables such as socio economic status, parents education etc. and as such as cannot be used to infer any causality.

- *Impaired literacy*

In a cross-sectional study to compare the relationship between hyperopia and levels of literacy standards in children in Wales, it was found that the children with the lowest test scores were more strongly hyperopic [36]. The authors conclude that children with specific deviations of refractive error are better suited to certain tasks. The sample selection is non-random and based on children presenting for screening. Moreover, the analysis did not include any adjustment for confounders. Hence the study has limited generalizability.

2) Psycho-social impacts

Three cross-sectional studies [49, 51, 55], and one qualitative study [49] focuses on psycho-social impacts of URE on children.

- *Self-esteem*

Dias *et al*. [51] investigated refractive error and self-esteem. This study examined the relationship between self-esteem of myopic children and ocular demographic relationships. Less symptomatic children (score < 10) evaluated themselves more positively in all areas ($p < 0.05$), except athletic competence. Older age at myopia diagnosis and shorter length of time since diagnosis were significantly associated with increased self-esteem in only one domain (behavioural conduct and physical appearance, respectively) .

A study highlighting the impact on self-esteem was conducted by Odedra *et al.* [49]. In this study, it was highlighted that based on the fact that children wear spectacles, the level of their self-esteem was somehow affected ($P<0.05$). The study showed that there was a relationship between spectacle wearing and self-esteem, which was positive based on the appearance of the child. Beliefs and attitude about spectacles, as a measure of psychosocial impact, was investigated and indicated to have a greater impact on the use of spectacles to the individual and their social environment.

- Sleep disorder

Zhou *et al*. [55] investigated sleep patterns in their study on disordered sleep and myopia risk. On average, the time spent on some daily activities such as reading, sleep-disorder, breathing and daytime sleeping did not differ between myopic and non-myopic children. There was however a contradiction from the population under study on the evidence of association between myopia and parental-reported poor sleeping. Myopia and disordered sleep were both common in the cohort of myopes there was no consistent evidence for an association between the two.

3) Quality of life

Ultimately, ten studies were on quality of life [14, 17, 20, 21, 23, 37, 50, 52, 53, 56]. Of these studies, two were on visual functioning [14, 17], 1 on well-being, and specifically on headaches [52] and 1 on accidents [23].

- *General quality of life*

Wong *et al*. [20] conducted a study on the visual impairment and its impact on health related quality of life in adolescents. The authors studied the differences in total scores between high and low myopes compared to non-myopes and found that they were not significant. Lack of significance was also observed between the self-reported mean scores by healthy adolescents. No significant difference was observed between hyperopes and non-hyperopes in total scores ($p = 0.54$), physical ($p=0.98$) and psychosocial ($p = 0.42$). The authors concluded that refractive errors in children do not have an impact on QOL. Kumaran *et al*. [50] conducted a qualitative study of refractive error and vision related quality of life in South Indian children. They also concluded that refractive errors in children do not have an impact on QOL. The lack of randomisation prevents us from generalising these results and further studies in this area are needed.

Shashidar *et al*. [53] investigated the social influence, study habits and health factors affecting scholastic performance. Their findings show that the incident of poor study habits and social factors were increased in low achievers of corporation schools, mainly in those with refractive error, not having help to study at home, not doing homework regularly, and reading only before exams. Adolescents who were attending school and doing their homework regularly were more from the private schools and this was significant ($p<0.01$).

A vision-related quality of life of schoolchildren with URE was investigated using three focus groups (for children) in a study in India. In this study, Kumaran *et al*. [50] used a holistic approach to exhibit hitches faced by children in their day to day life. It is not clear in the study whether the children were assessed on the outcome measures before the provision of eyeglasses but they were measured after

receiving eyeglasses. Some children remained uncorrected due to reasons such as ignorance, unbelief, and also social stigma among female children. There were improvements is some aspect such as academic performance and levels of confidence.

A retrospective study from two different groups, one with reading and writing difficulties, and the clinical control group was considered by Dusek *et al.* [37] to investigate the prevalence of refractive errors. Due to the nature of the study, masking was not done even though standardized procedures were maximized for each subject in order to minimize bias. The results of the study showed that there was significant difference between the two groups ($P<0.01$), but was not significant for all other measures of visual function ($P>0.05$).

Morgan *et al.* [56] investigated the education performance in after-school tutorial classes in an ecological study. Reduction in work load to children and allowing more outdoors time was discussed as a means to prevent high prevalence of myopia. Locations with high prevalence of myopia had high education performance and high engagement in after school tutorials.

- *Visual function*

Mutti *et al.* [21] explored a study to quantify the level of association between juvenile myopia and parental myopia. Interactions between parental myopia and near work were not statistically significant, indicating that there is no increase in risk as the number of parents with myopia increase. Near activities considered in this study were assumed working distance, weighted hours per week spent studying, reading for pleasure, watching television, and playing video games or working on the computer. It was concluded from this study that children with myopia spend significantly less time playing sports ($p<0.024$). There was no indication that kids will become heir to myopigenic environment or a susceptibility to the effects of near work from their parents.

Esteso *et al*. [14] examined the reporting of self-reported visual functioning in a rural setup on provision of spectalces on school-aged children. Visual acuity was measured twice, before the provision of spectacles and after (in four weeks' time). A tool to measure vision related quality of life among persons with refractive error was used with a score based mechanism, and a significant

improvement (P < 0.001) was seen after the provision of spectacles. The study was non-random and showed the impact of provision of spectacles to children on self-reported functions.

Congdon *et al.* [17] conducted a study of children in Chinese secondary schools in rural areas. This study aimed at evaluating the visual acuity, visual function, and prevalence of refractive errors amongst the children in the study sample, randomly selecting children from each given subgroup. . Among children with visual disability, not all had appropriate correction. More myopic refractive error was associated with worse self-reported visual acuity (P<0.001). The impact of refractive error on self-reported visual acuity was statistically significant, such that there was high correctable, and frequently uncorrected visual disability in the population under study.

- *Well-being (headaches)*

One study investigated well-being [52], determining the relationship between habitual refractive errors and headache complaints. In terms of headaches in girls, there is an association between the spherical components of habitual refractive error (especially hyperopia). In boys, there is an association with frequency of headaches and amount of burden (but a very small amount). This study set out to find an association and not causality. It is not clear how the authors decided on the chosen schools and no exclusion and inclusion criteria are provided. Furthermore, this study did not adjust for confounders in the analysis.

- *Accidents*

Zhang *et al*. [23] investigated myopia, spectacle wear and the risk of bicycle accidents. In univariate analysis male sex (odds ratio, 1.55; P .001) and spectacle wear (odds ratio, 1.38; P=.04) were associated with a higher risk of accident, but habitual visual acuity and myopia were ***not*** associated with crash risk after adjusting for age, sex, time spent riding, and risky riding behaviours. This was a randomly selected sample and the results are generalizable.

4) Impact of refractive error correction

- ✓ *Positive impacts of refractive error correction*

Esteso *et al*. [14] conducted a study in Mexico, on children, which showed significant improvement in self-reported visual functioning associated with spectacle wear among children with moderate levels of myopia. There was significant improvements noted in children receiving spectacles in the school based refractive error program. In addition, the Refractive Status Vision Profile (RSVP) total score and all subscales showed significant improvement, indicating that the program has a measurable beneficial effect on vision. In this study [14], children with myopia had a significant ($P<0.05$) mean improvement in total score after stratification by refractive error in the better-seeing eye at presentation. It was also noted that the mean perfection of children with mild myopia was somehow extra unassertive but still significant ($P < 0.05$). Unfortunately this study had a small sample size, the sampling method and the sample characteristics were not clearly described and the inclusion and exclusion criteria were not clearly explained.

Ma *et al.* [47] conducted a comparison of free glasses group and the control group which indicated that there was a significant difference between the two. From the model adjustment on the math score, allocation to free glasses, younger age, residence in the area and education from parents we significantly associated with higher endline math scores. Allocation of free glasses group had a much better effect on math test scores than either parental education or family wealth. The post hoc analysis on the use of black board showed that effect size was larger for free glasses group in classrooms where blackboards were being used more frequently than for the control group.

A significantly positive impact was also deducted from the RCT study by Hannum *et al.* [46]. In this study, it was suggested that vision glitches themselves are discriminatory of better-off children and more scholastically involved students, and this selectivity makes isolating the causal impact of glasses-wearing a difficult task. The propensity score matching estimates based on the GSCF advocate a significant outcome of glasses-wearing on standardized math and literacy tests.

A study aiming to evaluate how a group of myopic children view themselves in various self-esteem domains and whether any specific ocular or demographic characteristics are associated with self-

esteem was conducted by Dias [51], The overall result from the test for consistency using the Cronbach alpha test showed that generally normative sample was better than the Correction of Myopia Evaluation Trial (COMET). Of the children partaking in the COMET, boys recorded higher than the normative boys on scholastic ability ($P < 0.05$).

The cross sectional study considered by Hannum *et al.*, [46], on a different arm showed a positive impact on the group of children who received glasses. Analysis of the GVIP intervention data shows that those who received glasses were less likely to fail a class, which is a positive impact. The findings of this study were though consistent with the common sense notion that correcting vision supports learning.

Odedra *et al*. [49], in a qualitative study among children in Tanzania to determine the barriers to spectacle wear reported that most of the children who revealed that they had obtained spectacles were positive about their appearance and usefulness. A significant number agreed that they liked the appearance of their spectacles and even more claimed that spectacles improved their vision.

— *Negative impacts of refractive error correction*

In the qualitative study conducted by Kumaran *et al*. [50], children self-reported headaches, eye strain, eye pain, watery eyes, and difficulty in recognizing faces, performing near tasks, and seeing writing on the chalkboard before spectacle correction. Following correction, children self-reported that they felt inferior because they have a problem seeing and were teased by their friends, which spoilt their moods. The study provided valuable insight into the negative issues related to spectacle wear. However, the study designs do not lean towards any conclusions but the data provided could serve as a basis for the design of future studies that should be a combination of quantitative and qualitative measures.

The study by Odedra *et al*. [49] found via focus groups that teasing was an issue following spectacle correction. A few children were unhappy with their appearance and did not think that spectacles improved their vision with some reporting being teased when they wore their spectacles.

There is sufficient indication to show that children with specific deviations of refractive error are better suited to certain tasks. Williams *et al.* [36] showed a negative impact on interventions. This study showed a greater number of children who failed the fogging test and the others (non-fogging test failures) failed to meet requirements (6/6 criteria). Majority of the fogging test failures were obtained were more of refractive errors though few were on borderline myopes and have been excluded from the analysis. There was no correlation between anisometropia and NFER score for the fogging test referral group (r=0.05).

DISCUSSION

There is an increased awareness of the need to quantify the impact of URE for policy change, advocacy efforts and greater accountability to communities and funders. However little emphasis has been placed on conducting such reviews and this review represents the first systematic review on the impact of URE in children. The lack of focus in this area has led to limited consistency in research methodology. Furthermore, only two RCTs are included and there were more cross-sectional studies (16 studies), which limit our capacity to draw appropriate conclusions. Furthermore, the different research approaches and tools employed have prevented a meta-analysis from being conducted hence this study presented outcomes elicited through a descriptive analysis. The cost and complexity of RCTs, probably, limit such studies from being conducted – however - given the investment in child eye health by various governments and non-profit agencies, such investment may assist in upscaling programs through advocacy efforts and represent a good return on investment.

From the 21 studies that met our inclusion criteria we identified the following areas of impact viz. educational, psychosocial, quality of life outcomes as well as negative outcome aspects such as teasing, bullying and poor self-esteem. We were unable to address the economic outcomes as a possible consequence of many economic impact studies addressing loss productivity which does not in the short-term include children. It will be useful however to address both the long-term economic impact of URE in children as well as cost to society in the short term to support children who spend their lives as blind and visually impaired and require additional social and economic support. In terms

of the generalizability (external validity) only 6 [17, 23, 35, 47, 49, 54] used random sampling and so the results can be generalized to the population of children from which the sample was selected. It should be noted however that some studies included all schools in a limited area and so the results might have limited applicability. In the qualitative study in Tanzania a sub-set of children were selected for focus group discussions who were and who were not wearing their spectacles three months after they were dispensed. This study was embedded in a cluster randomised trial of children in 42 secondary schools in a large city who were randomised to free spectacles or a prescription for spectacles [49]. The findings are therefore likely to reflect the views of other urban adolescents in Tanzania.

Despite the above limitations the findings provide some insight into the factors influencing the impact of URE on children. There is much reference in the literature as well as in the public health discourse of the educational impact of URE in children. In many instances this is accepted as, intuitively, it makes sense to many. However in a space where governments are courted by competing interests in health care, have limited resources for health care and take decisions on investment based on the public perception and response to an issue, the burden of proof of impact has become much higher. Thus, the educational outcome measured in some of the studies can provide a strong basis for advocacy with not only with the ministry of health but also the education ministry. However the limited studies in this review, particularly RCT restricts the capacity of such info to be used widely. Additionally, the RCTs conducted have been identified as having methodological challenges and as such there is dire need for RCTs that can be designed to address some of the shortfalls identified in this review. The debate regarding the Ma et al trial [47, 57] highlights the complexity of attributing causality in RCTs that explore the impact of spectacle wear on academic performance. This is compounded by the fact that there is evidence that myopia is associated with increased school grades [22].It highlights the need for a RCT that has the rigour to overcome the definition bias (better eye vs. any eye) and the other methodological challenges that have been raised.

The cross-sectional studies conducted should be taken to be indicative of possible impact and conducted with a RCT design to provide evidence of much greater credibility. Only one study had a small sample size [50] of 27 while other studies have included good sample sizes with the Chinese studies having large sample sizes that assist in enhancing the credibility of such studies. The smaller studies should be repeated with larger sample sizes and a RCT design.

In summary, the evidence from the review provides the following indications:

- URE has possible association with educational outcomes however there is a need to address the measurement tools. Using mathematics as an indication of the impact of URE raises the question of the appropriateness in societies where teaching resources and cultural interest in the subject is lacking.
- It is critical that common tools for the measurement of the impact of URE are developed.
- There is a need for more studies to quantify the impact of URE on educational outcomes and RCTs, in particular.
- There is a dearth of studies addressing the psychosocial effects and issues such as impact on disordered sleep or accidents with bicycles or other accidents need to be investigated. The single studies on these issues and the lack of RCTs limit our capacity to make conclusive statements on these issues.
- Loss of self-esteem has been identified as a possible area of refractive error impact [51] and the impact of refractive correction [49, 50] however further research is needed to investigate this issue.
- The impact of correction is an issue that needs to be addressed as often the uptake of spectacles is identified as a challenge.
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CONCLUSION

The review identifies limited studies addressing the impact of URE. While these may be indicative of possible areas of impact; the small number of studies, the lack of RCTs, and the inconsistency and geographical sensitivity of the tools employed limit definitive conclusions. For example, when

evaluating the link between refractive error and academic performance, it becomes clear that the relationship is intricate and complex. Difficulties in seeing distant objects may be due to myopia, which affects school-aged children, particularly in Asia [8, 10]. There is a high prevalence of myopia in China (approximately 60% in rural areas [10, 17] and 80% in ethnically Chinese urban populations [59], which could result from a higher concentration on near work school activities and life-style changes which have limited the time children spend outdoors [56]. However, studies have also shown that higher educational attainment is associated with a greater risk of myopia and myopia progression [36, 56]. Thus the literature does not show that there is a clear relationship between myopia and reduced school performance. Further research and particularly investment in research is critically needed to quantify the impact of URE in children as rigorous evidence on the impact of URE on a number of parameters is limited.

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