Review Article

Prevalence of Sports-Related Eye Injuries: A Systematic Review and Meta-Analysis

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Abstract

Background and Objectives: More than 42,000 sports-related eye injuries are brought to emergency units every year. Although multiple studies have been conducted on the prevalence of sports-related eye injuries and consequent outcomes, no systematic review has been conducted to summarize the findings of these studies. Therefore, this study was conducted to systematically review the prevalence of sports-related eye injuries and blindness. **Methods:** A systematic search was conducted to locate the studies that addressed the global prevalence of sports-related eye injuries. The located articles (132 studies) were screened on different levels, and their quality was assessed using the JBI checklist for prevalence studies. The statistical analysis was conducted using CMA v. 3.2, and the results were considered significant for $P < 0.05$. **Results:** From a total of 132 studies, 27 articles were included for analyzing the prevalence of sports-related blindness which was 7.2%. Further, 51 studies were used for analyzing the prevalence of sports-related eye injuries in total eye injuries, and the obtained value was 9.3%. Moreover, 29 studies were analyzed to calculate the proportion of sports-related eye injuries to total sports injuries, and the obtained value was 6.7%. **Conclusion:** Findings of this study suggest that sport-related eye injuries account for a major part of eye injuries and a considerable portion of these traumas lead to blindness.

Keywords: Blindness, eye, injury, prevalence, sports, trauma

Introduction

According to the ICD-10 categorization, developed by the World Health Organization (WHO) in 2006, blindness is defined as the visual field of <10° and the visual acuity of <20/400 with the best possible correction. Legal blindness is referred to as visual acuity of <20/200 with the best corrected visual acuity (BCVA).[1,2]

It is estimated that more than 80% of visual impairments are actually both preventable and treatable. Major causes of blindness are cataracts and glaucoma, which can occur due to eye traumas. These conditions that are among the main causes of unilateral blindness in the world, despite happening abruptly, are preventable.[3,4]

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Eye injuries can occur in the workplace, at home, or during sport activities. Therefore, sports-related eye injuries account for a major portion of eye traumas. Eye injuries not only afflict athletes' health but can also affect their families, club, and society.[5]

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More than 42,000 cases of sport-related eye injuries are brought to emergency units every year, about a quarter of them end up with some sort of visual impairment. It is reported that more than 10% of the eye injuries in the United States are related to doing sports. There have been 111 cases of enucleation within 12 years, of which 10% were sports-related. 24% of eye injuries in India are sports-related.[6]

Treating eye injuries are also costly. More than 100,000 visits are made to the medical centers because of eye injuries every year, costing about 175 million dollars.[7]

Sports that cause the most eye injuries vary in different countries.[8] Sports-related eye injuries and consequent visual impairments and blindness can be prevented by modifying the sport's rules and promoting safety measures. These measures can also decrease the costs of treatment and rehabilitation.[9] Accurate and new studies should take place to inform policymakers in the planning of preventive measures and enhancing rehabilitation programs for patients with visual impairments.[3]

Despite the existence of multiple studies on the prevalence of sports-related eye traumas and relating outcomes, no systematic review has been conducted to summarize the findings of these studies. Therefore, this study was conducted to systematically examine the prevalence of sports-related eye trauma and blindness.

Methods

All ethical considerations for systematic reviews and meta-analyses, including the ethics of using scientific literature, were taken into consideration in this review.

Data sources

A systematic search was conducted to locate studies addressing the prevalence of sports-related eye injuries. The used keywords were eye, injury, damage, trauma, and sport. A combination of controlled (MeSH, Emtree) and free text keywords in multiple databases was used to formulate the search strategy. Medline (PubMed), Scopus, Web of Science, and Embase databases were searched for articles published between June 1990 and October 2019 without any language restrictions. The search strategies for Embase and PubMed were appended.

To locate Persian articles, Iran's databases including SID, IranDoc, and Barakat knowledge network systems were searched. Proquest, Gray.net, and Google Scholar were searched for gray literature, theses, and materials that were presented in conferences. The WHO website was searched as well. To get more information about the published and unpublished articles, corresponding people were reached, and at last, the references of included studies were searched to complete the searching process.

Inclusion criteria

- Observational studies (cross-sectional, cohort) that examined the sports-related eye injuries
- Published articles from January 1990 to October 2019
- Articles presented in conferences.

Exclusion criteria

- Articles lacking the predetermined quality
- Republished articles using the same samples
- Review articles, editorial letters, recommendations, and case report articles.

Data extraction and assessing the quality of articles

Once the studies were located, the screening took place at three different levels by two reviewers. At first, the titles of all articles were assessed and those not aligning with the review objectives were excluded. Then, the abstract and full-text of located articles were assessed, and studies that did not meet the inclusion criteria were identified and excluded. In the next level, two reviewers assessed the risk of bias using the JBI checklist.[10] A third reviewer was used to settle any disagreements that could not be resolved through discussion. Extracted data were summarized in extraction forms. Extraction data included lead author, publication year, country, sample size, number of sports-related blindness cases, number of sports-related eye injuries, and type of sports. EndNote® X7.5 by Camelot UK Bidco Limited, Philadelphia, Pennsylvania was used to organize and assess the titles and abstracts, as well as to recognize duplicate cases.

Methods of analysis

Heterogeneity between studies was assessed using Cochran (Q) and I^2 that examine the percentage of variability between studies. $I^2 < 50\%$ was considered an indicator of homogeneity. The random-effects model was used to synthesize findings. The subgroup analysis was conducted based on the type of injury and the type of sports. The statistical analysis was conducted using CMA® v. 3.2 by Biostat, Inc. Englewood, New Jersey, and the results were considered significant for $P < 0.05$. Moreover, the Egger's regression test and funnel plot were used to address the publication bias.

Results

Description of studies and search results

In this study, 2084 studies were identified in the systematic search of data sources; 629 duplicate articles were excluded and 1252 studies were excluded after assessing titles and abstracts of articles. After assessing the full text of the remaining studies, 71 articles were excluded. Eventually, 132 were included in the meta-analysis. The consort flowchart for the identified and included studies is shown in Figure 1.

Descriptions of included studies in the meta-analysis are described in Tables 1-4.

Critical appraisal

The quality of included studies was assessed using the JBI Critical Appraisal Checklist for Studies Reporting Prevalence Data, and the results are demonstrated in Appendix 1 as supplementary digital material.

Table 1: Descriptions of the included studies in the meta-analysis of the prevalence of sports-related eye injuries in total eye injuries

Author/year	Country	Total eye injuries	Total sports-related eye injuries	Study duration
Moon S. *et al*. (2016)	Korea	5356	446	7 months
Haring R. S. *et al*. (2016)	USA	5,541,434	154,474	5 years
Wong T. Y. *et al*. (2000)	USA	5450	609	10 years
Chen A. J et al. (2013)	USA	1455	36	
Malagola R. *et al*. (2012)	Italy	203	62	12 years
Huai-Yu Q. *et al*. (2011)	China	502	181	1 year
Saeed A. *et al*. (2010)	Ireland	517	54	6 years
Cillino S. *et al*. (2008)	Italy	245	43	5 year
Woo J. H. *et al*. (2006)	Singapore	133	8	7 weeks
MacEwen, C. J. *et al*. (1999)	Scotland	93	15	1 year
Alfaro, D. V. 3rd *et al*. (2005)	USA	9293	732	
Archambault C. *et al*. (2018)	Canada	289	43	3 years
Haavisto, A. K. *et al*. (2017)	Finland	202	38	1 year
Sahraravand, A, *et al*. (2018)	Finland	118	10	1 year
Soong, T. K. W. *et al*. (2011)	Malaysia	546	17	1 year
Poon, A. S. *et al*. (1998)	Hong kong	60	5	
Strahlman E. *et al*. (1990)	America	57	15	
Gordon K. D. (2012)	Canada	104	9	1 year
Oum B. S. *et al*. (2004)	South Korea	1809	128	6 years
Umeh R. E. *et al*. (1997)	Nigeria	228	54	
Desai P. *et al*. (1996)	Scotland	417	52	1 year
Chang C. H. *et al*. (2008)	Taiwan	160	5	2 years
Maurya R. *P* et al. (2019)	India	402	96	4 years
Zagelbaum B. M et al. (1993)	USA	530	19	1 year
Sahraravand A. *et al*. (2017)	Finland	831	100	1 year
Monestam E. *et al*. (1991)	Sweden	927	26	1 year
Drolsum L. (1999)	Norway	553	76	10 years
Karaman K. *et al*. (2004)	Croatia	383	14	
Taher A. A. Y. (1996)	Iran	367	2	
McGwin G. Jr. *et al*. (2006)	US	1,122,308	153,981	
Alfaro D. V. 3rd *et al*. (2005)	US	9293	732	
Pollard. K. A. *et al*. (2012)	US	43,240	10,417	20 years
Jafari A. *et al*. (2012)	Iran	1950	47	
Bhatti M. A. *et al*. (2011)	Pakistan	93	24	1 year
Ghosh F. *et al*. (1995)	Sweden	272	109	33 months
Awidi A. *et al*. (2018)	US	53	5	10 years
Pandita A. *et al*. (2012)	New Zealand	821	62	10 years
McCarty C. A. *et al*. (1999)	Australia	1403	74	
Capoferri C. *et al*. (1994)	Italy	659	65	
Hoskin A. K. *et al*. (2014)	Australia	489	75	
Hilber D. *et al*. (2010)	US	704	32	
Bro T. *et al*. (2016)	Sweden	2483	296	5 years
Leivo T *et al*. (2007)	Finland	565	94	6 months
Lynch P. *et al*. (1997)	Ireland	5835	98	1 year
Liu M. L. *et al*. (2010)	Taiwan	156	9	
Fong L. P. (1995)	Australia	6308	378	1 year
Matsa E. *et al*. (2018)	US	163,431	23,134	1 year
C	Nigeria	67	5	3 years
Yanko L. *et al*. (1995)	Israel	2416	121	3 years
Fong L. P. (1994)	Australia	14,000	700	2 years
Zhang Y. *et al*. (2009)	China	716	126	
Ai-Ourainy I. A. *et al*. (1991)	Scotland	329	45	2 years

Table 2: Descriptions of the studies included in the meta-analysis of the prevalence of blindness in total sports-related eye injuries

Author	Year	Sports-related eye injuries	Blindness
Drolsum L.	1999	76	3
Karaman K. *et al.*	2004	14	1
Ghosh F. *et al.*	1995	109	2
Pandita A. *et al.*	2012	62	7
Yanko L. *et al.*	1995	121	12
Fong, L. P.	1994	175	33
Ai-Ourainy I. A. *et al.*	1991	45	0
Capao Filipe J. A. *et al.*	2003	24	1
Filipe J. A. *et al.*	1997	84	5
Larrison W. I. *et al.*	1990	16	5
Hoskin A. K. *et al.*	2016	49	1
Barr A. *et al.*	2000	40	0
Capao Filipe J. A. *et al.*	2003	163	4
Kent J. S. *et al.*	2007	5	0
Capoferri C. *et al.*	1994	27	3
Alfaro D. V. 3rd *et al.*	2005	96	20
Kent D.	2006	25	0
Keles S. *et al.*	2014	10	4
Mason Iii J. O. *et al.*	2002	10	1
Lawson J. S. *et al.*	1995	26	15
Teller J. *et al.*	1990	39	2
Wedrich A. *et al.*	1993	19	0
Aburn N.	1990	29	0
Bunn J. W.	2008	39	0
Bro T. *et al.*	2016	167	1
Khan M. I. *et al.*	2008	59	7
Flynn T. H. *et al.*	2005	310	7

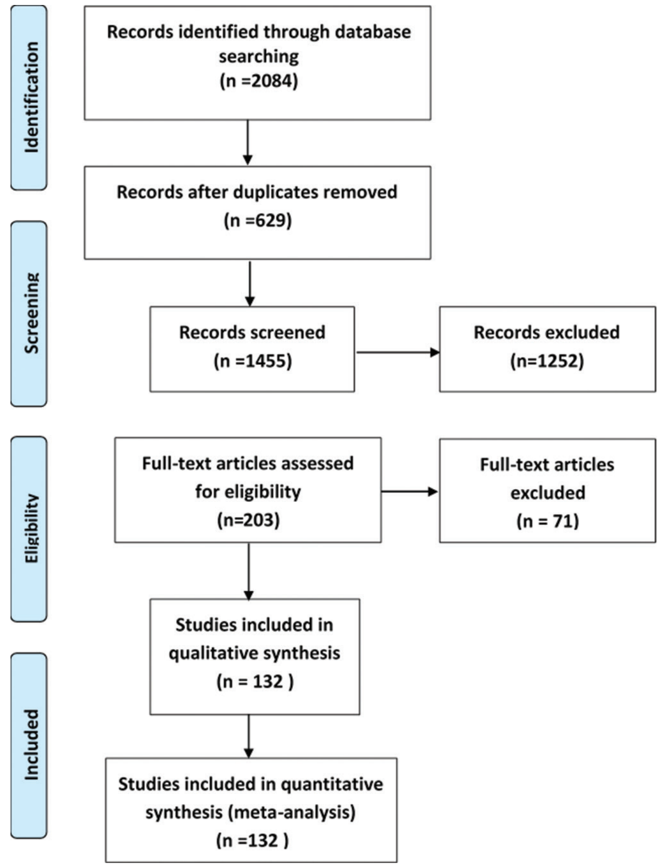


Figure 1: Flowchart of the review search results

Meta-analysis results

Prevalence of sports-related blindness in total sports-related eye injuries

Twenty-seven studies were included in the meta-analysis of the prevalence of sports-related blindness in total sports-related injuries [Figure 2]. The prevalence of sports-related eye blindness in total sports-related eye injuries is 7.2%, using the random-effects model (P = 7.2%, 95% confidence interval [CI] = 4.5–11.3).

Prevalence of sports-related eye injuries in total eye injuries

Fifty-one studies were included in the meta-analysis of sports-related eye injuries in total eye injuries [Figure 3]. Heterogeneity between studies was significant (Q = 24424.18, df = 26, I^2 = 99.98, $P < 0.001$). Further, 6,951,552 cases of eye trauma were reported in these studies. Using the random-effects model, the prevalence of sports-related eye injuries in total eye injuries was 9.3% (P = 9.3%, 95% CI = 6.9–12.3).

Prevalence of sports-related eye injuries in total sports injuries

Twenty-nine studies were included in the meta-analysis of the prevalence of sports-related eye injuries in total sports injuries [Figure 4]. Heterogeneity between studies was significant (Q = 522.58, df = 28, I^2 = 94.64, $P < 0.001$). In addition, 16,601 cases of sports injuries were reported in these studies. Using the random-effects model, the prevalence of sports-related eye injuries in total sports injuries was 6.7% (P = 6.7%, 95% CI = 4.8–9.1).

The examined sports were divided into three categories of low, moderate, and high risk based on the chance of the eye being hit hard enough to cause injury [Table 5]. Subgroup analyses were sorted by the risk of different sports. The results of subgroup analyses are shown in Figure 5 and Table 6.

Prevalence of sports-related eye injuries in total eye injuries, sorted by the type of injury

Twenty-five studies were included in the meta-analysis of the prevalence of sports-related eye injuries in total eye injuries, sorted by the type of injury [Figure 6]. In addition, 3125 cases of eye injuries, sorted by the type of injury, were reported in these studies. Twenty-one percent of the total close globe injury (CGI) eye injuries and 21% of the total orbital fractures were due to sports. Sports had a lesser share in other kinds of injuries. Further, the random-effects model was used. The results are shown in Table 7.

Prevalence of blindness in sports-related eye injuries sorted by country

Twenty-seven studies were included in the meta-analysis of the prevalence of sports-related blindness in sports-related

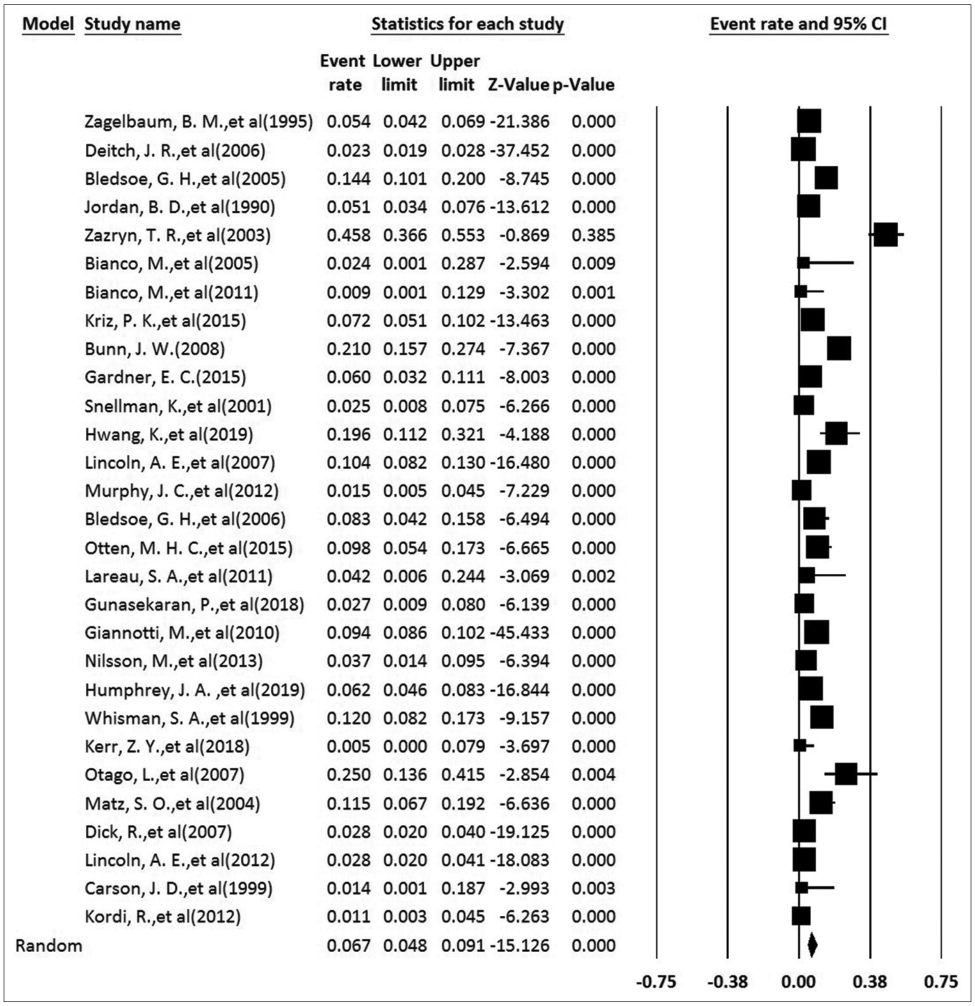


Figure 2: Prevalence of sports-related blindness in total sports-related injuries

eye injuries, sorted by country [Figure 7]. In addition, 26 studies were conducted in high-income countries and one was conducted in an upper-middle-income country. The meta-analysis was conducted using a random-effects model, and the prevalence of blindness in sports-related eye injuries was 6.58 in high-income countries and 40 in the upper-middle country (Turkey) (P = 6.58%, 95% CI = 4.08–10.44).

Prevalence of sports-related eye injuries in total eye injuries, sorted by country

Fifty-two studies were included in the meta-analysis of the prevalence of sports-related eye injuries in total eye injuries, sorted by country [Figure 8]. Further, 43 studies were conducted in high-income countries, 5 studies in upper-middle-income countries, and 4 studies in lower-middle-income countries. Results of the meta-analysis for the prevalence of sports-related eye injuries sorted by the country for countries with high, upper-middle, and low income were 9.02, 6.00, and 19.10, respectively [Table 8].

Prevalence of sports-related eye injuries in total sports injuries, sorted by country

Twenty-nine studies were included in the meta-analysis of the prevalence of sports-related eye injuries in total sports injuries, sorted by country [Figure 9]. Further, 28 studies were conducted in high-income countries and one was conducted in an upper-middle-income country. The prevalence of sports-related injuries in total sports injuries sorted by country was 6.9 in high-income countries and 1.1 in the upper-middle country (Iran).

Prevalence of sports-related eye injuries in total eye injuries, sorted by the type of injury

Twenty-five studies were included in the meta-analysis of the prevalence of sports-related eye injuries, sorted by the type of injury [Figure 10]. Moreover, 17 studies were conducted in high-income countries, 4 in upper-middle-income countries, and 4 in lower-middle-income countries. Results of the meta-analysis for the prevalence of sports-related eye injuries in total eye injuries sorted by the type of injury for countries with high, upper-middle, and low income were 18.03, 20.66, and 13.59, respectively [Table 9].

Publication bias

To examine the publication bias, a funnel plot was drawn, and as shown in the illustrated funnel plot [Figure 11], heterogeneity is visible among the included studies. However,

Model	Study name	Event rate	Lower limit	Upper limit	Z-Value	p-Value
	Ai-Ourainy, I. A.,et al(1991)	0.137	0.104	0.178	-11.482	0.000
	Alfaro, D. V., 3rd,et al(2005)	0.079	0.073	0.084	-63.860	0.000
	Archambault, C.,et al(2018)	0.149	0.112	0.195	-10.552	0.000
	Awidi, A.,et al(2018)	0.094	0.040	0.207	-4.813	0.000
	Bhatti, M. A.,et al(2011)	0.258	0.179	0.356	-4.456	0.000
	Bro, T.,et al(2016)	0.119	0.107	0.133	-32.292	0.000
	Capoferri, C.,et al(1994)	0.099	0.078	0.124	-16.935	0.000
	Chang, C. H.,et al(2008)	0.031	0.013	0.073	-7.558	0.000
	Chen, A. J.,et al(2013)	0.025	0.018	0.034	-21.771	0.000
	Cillino, S.,et al(2008)	0.176	0.133	0.228	-9.212	0.000
	Desai, P.,et al(1996)	0.125	0.096	0.160	-13.147	0.000
	Drolsum, L.(1999)	0.137	0.111	0.169	-14.872	0.000
	Eze, K. C.,et al(2009)	0.075	0.031	0.167	-5.416	0.000
	Fong, L. P.(1994)	0.050	0.047	0.054	-75.930	0.000
	Fong, L. P.(1995)	0.060	0.054	0.066	-51.894	0.000
	Ghosh, F.,et al(1995)	0.401	0.344	0.460	-3.252	0.001
	Gordon, K. D.(2012)	0.087	0.046	0.158	-6.757	0.000
	Haavisto, A. K.,et al(2017)	0.188	0.140	0.248	-8.122	0.000
	Haring, R. S.,et al(2016)	0.028	0.028	0.028	-1376.341	0.000
	Hilber, D.,et al(2010)	0.045	0.032	0.064	-16.826	0.000
	Hoskin, A. K.,et al(2014)	0.153	0.124	0.188	-13.613	0.000
	Huai-Yu, Q.,et al(2011)	0.361	0.320	0.404	-6.164	0.000
	Jafari, A.,et al(2012)	0.024	0.018	0.032	-25.065	0.000
	Karaman, K.,et al(2004)	0.037	0.022	0.061	-12.016	0.000
	Leivo, T.,et al(2007)	0.166	0.138	0.199	-14.266	0.000
	Liu, M. L.,et al(2010)	0.058	0.030	0.107	-8.134	0.000
	Lynch, P.,et al(1997)	0.017	0.014	0.020	-39.948	0.000
	MacEwen, C. J.,et al(1999)	0.161	0.100	0.250	-5.848	0.000
	Malagola, R.,et al(2012)	0.305	0.246	0.372	-5.392	0.000
	Matsa, E.,et al(2018)	0.142	0.140	0.143	-254.008	0.000
	Maurya, R. P.,et al(2019)	0.239	0.200	0.283	-9.910	0.000
	McCarty, C. A.,et al(1999)	0.053	0.042	0.066	-24.180	0.000
	McGwin, G., Jr.,et al(2006)	0.137	0.137	0.138	-670.207	0.000
	Monestam, E.,et al(1991)	0.028	0.019	0.041	-17.823	0.000
	Moon, S.,et al(2016)	0.083	0.076	0.091	-48.503	0.000
	Oum, B. S.,et al(2004)	0.071	0.060	0.084	-28.084	0.000
	Pandita, A.,et al(2012)	0.076	0.059	0.096	-18.964	0.000
	Pollard, K. A.,et al(2012)	0.241	0.237	0.245	-102.057	0.000
	Poon, A. S.,et al(1998)	0.083	0.035	0.185	-5.134	0.000
	Saeed, A.,et al(2010)	0.104	0.081	0.134	-14.943	0.000
	Sahraravand, A.,et al(2017)	0.120	0.100	0.144	-18.657	0.000
	Sahraravand, A.,et al(2018)	0.085	0.046	0.150	-7.199	0.000
	Soong, T. K. W.,et al(2011)	0.031	0.019	0.050	-13.952	0.000
	Strahlman, E.,et al(1990)	0.263	0.165	0.392	-3.423	0.001
	Taher, A. A. Y.(1996)	0.005	0.001	0.022	-7.343	0.000
	Umeh, R. E.,et al(1997)	0.237	0.186	0.296	-7.511	0.000
	Wong, T. Y.,et al(2000)	0.112	0.104	0.120	-48.216	0.000
	Woo, J. H.,et al(2006)	0.060	0.030	0.116	-7.538	0.000
	Yanko, L.,et al(1995)	0.050	0.042	0.060	-31.549	0.000
	Zagelbaum, B. M.,et al(1993)	0.036	0.023	0.056	-14.090	0.000
	Zhang, Y.,et al(2009)	0.176	0.150	0.206	-15.731	0.000
Random		0.093	0.069	0.123	-13.986	0.000

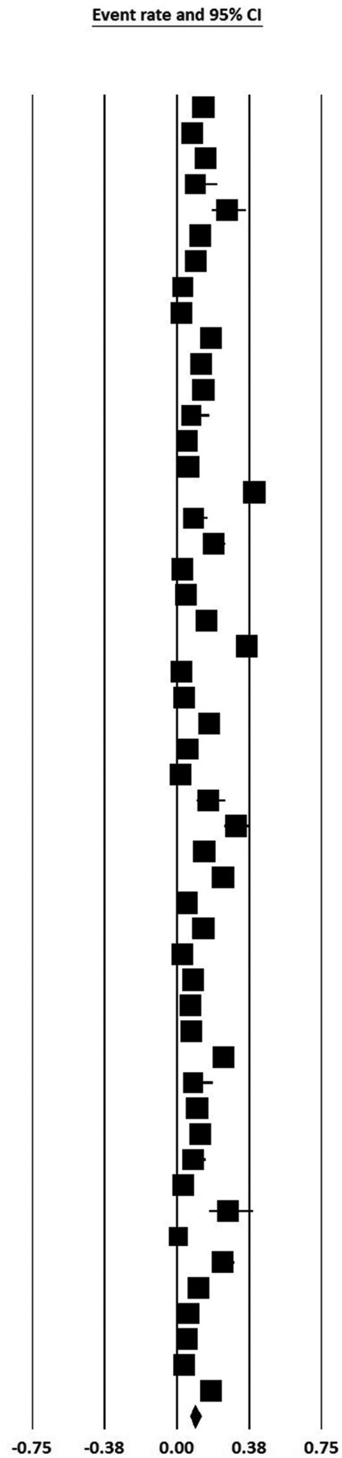


Figure 3: Prevalence of sports-related eye injuries in total eye injuries

according to the results of the Egger's regression test, there was no significant publication bias among the included studies ($t = 0.57$, df = 27, $P = 0.57$).

Discussion

In the quality appraisal of studies reporting the prevalence of sports-related eye injuries, it was observed that 30% of the analyses of the studies were not complete. Thus, the prevalence of sports-related blindness sorted by sex, age, and type of sports could not be reported.[11-17] Further, four studies did not use a standard process for collecting data.[16,18-20]

In the quality appraisal of studies reporting the prevalence of sports-related eye injuries sorted by the type of the injury and studies reporting the prevalence of sports-related

Model	Study name	Event rate	Lower limit	Upper limit	Z-Value	p-Value
	Drolsum, L.(1999)	0.039	0.013	0.115	-5.418	0.000
	Karaman, K.,et al(2004)	0.071	0.010	0.370	-2.472	0.013
	Ghosh, F.,et al(1995)	0.018	0.005	0.070	-5.576	0.000
	Pandita, A.,et al(2012)	0.113	0.055	0.218	-5.137	0.000
	Yanko, L.,et al(1995)	0.099	0.057	0.167	-7.254	0.000
	Fong, L. P.(1994)	0.189	0.137	0.253	-7.551	0.000
	Ai-Ourainy, I. A.,et al(1991)	0.011	0.001	0.151	-3.172	0.002
	Capao Filipe, J. A.,et al(2003)a	0.042	0.006	0.244	-3.069	0.002
	Filipe, J. A.,et al(1997)	0.060	0.025	0.135	-5.985	0.000
	Larrison, W. I.,et al(1990)	0.313	0.136	0.567	-1.462	0.144
	Hoskin, A. K.,et al(2016)	0.020	0.003	0.131	-3.831	0.000
	Barr, A.,et al(2000)	0.012	0.001	0.167	-3.088	0.002
	Capao Filipe, J. A.,et al(2003)b	0.025	0.009	0.064	-7.274	0.000
	Kent, J. S.,et al(2007)	0.083	0.005	0.622	-1.623	0.105
	Capoferri, C.,et al(1994)	0.111	0.036	0.293	-3.396	0.001
	Alfaro, D. V., 3rd,et al(2005)	0.208	0.139	0.301	-5.312	0.000
	Kent, D.(2006)	0.019	0.001	0.244	-2.753	0.006
	Keles, S.,et al(2014)	0.400	0.158	0.703	-0.628	0.530
	Mason Iii, J. O.,et al(2002)	0.100	0.014	0.467	-2.084	0.037
	Lawson, J. S.,et al(1995)	0.577	0.385	0.748	0.781	0.435
	Teller, J.,et al(1990)	0.051	0.013	0.183	-4.019	0.000
	Wedrich, A.,et al(1993)	0.025	0.002	0.298	-2.558	0.011
	Aburn, N.(1990)	0.017	0.001	0.217	-2.859	0.004
	Bunn, J. W.(2008)	0.013	0.001	0.171	-3.070	0.002
	Bro, T.,et al(2016)	0.006	0.001	0.041	-5.097	0.000
	Khan, M. I.,et al(2008)	0.119	0.058	0.229	-4.981	0.000
	Flynn, T. H.,et al(2005)	0.023	0.011	0.047	-9.856	0.000
Random		0.072	0.045	0.113	-10.093	0.000

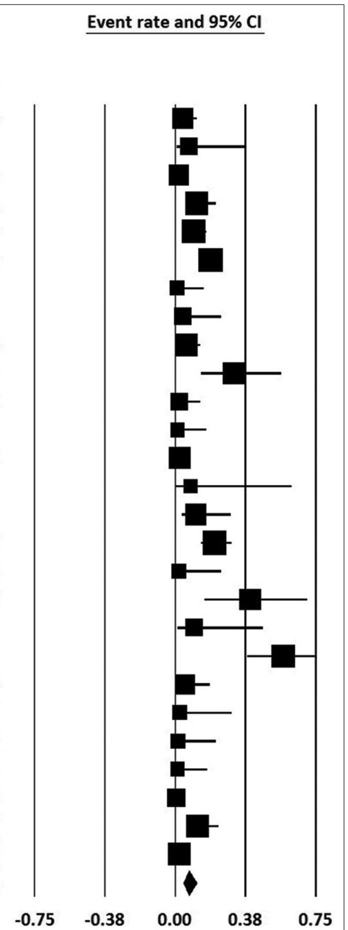


Figure 4: Forest plot of prevalence of sports-related eye injuries in total sports injuries

eye injuries in total eye injuries, there were two major problems: sampling and analysis. The samples did not present the population properly,[21-33] and all of the data were not reported or analyzed,[12-14,27,30,34-39] which made the gender or sex specification impossible. The eye injuries reported in these studies are the cases that were admitted to hospitals and eye care centers. This means minor eye injuries that were not referred to hospitals or admitted to private hospitals were not reported, which results in a lower evaluation.

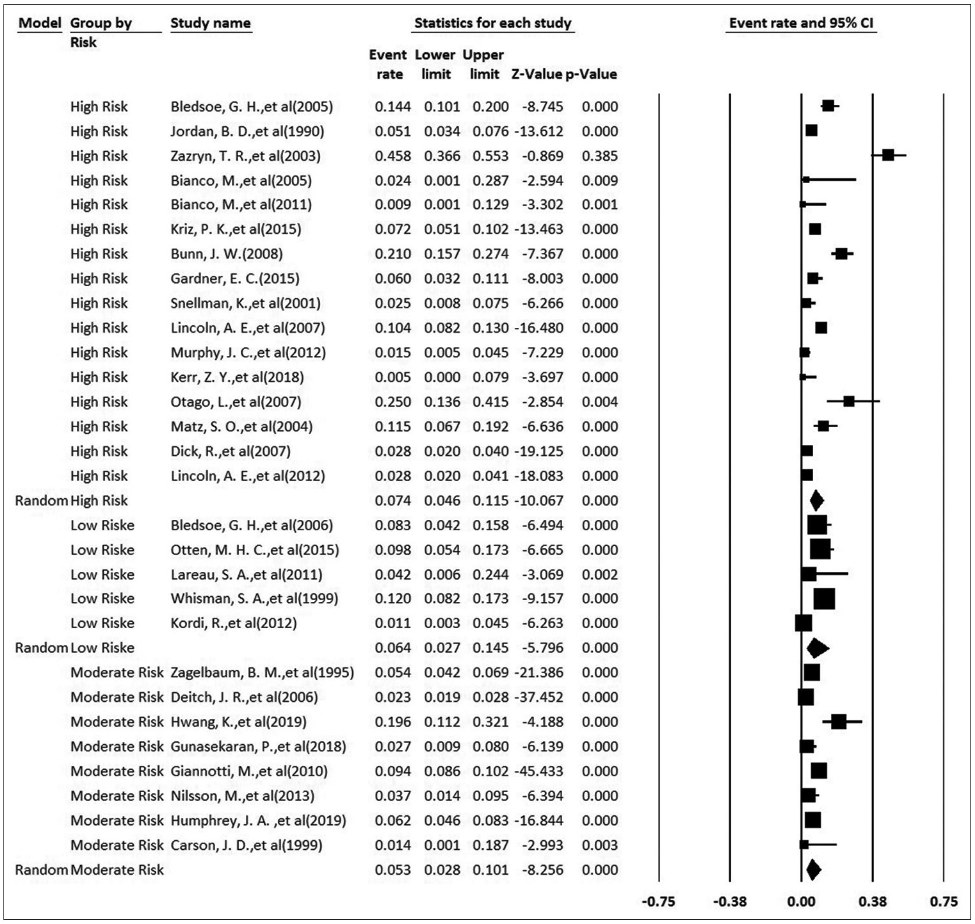
In the quality appraisal of studies reporting the prevalence of sports-related eye injuries in total sports injuries, the main problem was the sampling. About half of the studies had improper samples, which did not represent the population properly. Some of the studies only included certain sex, some reported all of the sports injuries, and some others only reported head and face injuries. Therefore, there was heterogeneity between the studies.[40-53] Some of the studies did not specify any standard process for the diagnosis of eye injuries.[41,44,46,54-56] It is recommended for future studies to use a standard process for diagnosis and report the age, sex, and type of sport of patients with eye injuries.

Prevalence of the consequent blindness of sports-related eye injuries

Based on the findings of 27 studies examining sports-related blindness, 1839 cases of sports-related eye injuries were reported that 7.2% of them went blind. Included studies had accepted the legal definition of blindness, and all of them were conducted in high-income countries and no studies from upper-middle-income and lower-middle-income countries were found to make a comparison between countries that have different economic status. The numerous studies on this topic in high-income countries indicate the grave importance of this condition for economic powers because visual impairments not only affect the individuals but have an economic burden on the healthcare system. Therefore, conducting similar studies is recommended for upper-middle-income and lower-middle-income countries.

Prevalence of sports-related eye injuries in total eye injuries

Fifty-one studies were included in the meta-analysis of the prevalence of sports-related eye injuries in total eye injuries. Of the 6,951,552 reported cases, 9.3% were due to doing sports. These studies mostly took place in high-income and upper-middle-income countries and only



Model	Group by Risk	Study name	Event rate	Lower limit	Upper limit	Z-Value	p-Value
	High Risk	Bledsoe, G. H.,et al(2005)	0.144	0.101	0.200	-8.745	0.000
	High Risk	Jordan, B. D.,et al(1990)	0.051	0.034	0.076	-13.612	0.000
	High Risk	Zazryn, T. R.,et al(2003)	0.458	0.366	0.553	-0.869	0.385
	High Risk	Bianco, M.,et al(2005)	0.024	0.001	0.287	-2.594	0.009
	High Risk	Bianco, M.,et al(2011)	0.009	0.001	0.129	-3.302	0.001
	High Risk	Kriz, P. K.,et al(2015)	0.072	0.051	0.102	-13.463	0.000
	High Risk	Bunn, J. W.(2008)	0.210	0.157	0.274	-7.367	0.000
	High Risk	Gardner, E. C.(2015)	0.060	0.032	0.111	-8.003	0.000
	High Risk	Snellman, K.,et al(2001)	0.025	0.008	0.075	-6.266	0.000
	High Risk	Lincoln, A. E.,et al(2007)	0.104	0.082	0.130	-16.480	0.000
	High Risk	Murphy, J. C.,et al(2012)	0.015	0.005	0.045	-7.229	0.000
	High Risk	Kerr, Z. Y.,et al(2018)	0.005	0.000	0.079	-3.697	0.000
	High Risk	Otago, L.,et al(2007)	0.250	0.136	0.415	-2.854	0.004
	High Risk	Matz, S. O.,et al(2004)	0.115	0.067	0.192	-6.636	0.000
	High Risk	Dick, R.,et al(2007)	0.028	0.020	0.040	-19.125	0.000
	High Risk	Lincoln, A. E.,et al(2012)	0.028	0.020	0.041	-18.083	0.000
Random	High Risk		0.074	0.046	0.115	-10.067	0.000
	Low Riske	Bledsoe, G. H.,et al(2006)	0.083	0.042	0.158	-6.494	0.000
	Low Riske	Otten, M. H. C.,et al(2015)	0.098	0.054	0.173	-6.665	0.000
	Low Riske	Lareau, S. A.,et al(2011)	0.042	0.006	0.244	-3.069	0.002
	Low Riske	Whisman, S. A.,et al(1999)	0.120	0.082	0.173	-9.157	0.000
	Low Riske	Kordi, R.,et al(2012)	0.011	0.003	0.045	-6.263	0.000
Random	Low Riske		0.064	0.027	0.145	-5.796	0.000
	Moderate Risk	Zagelbaum, B. M.,et al(1995)	0.054	0.042	0.069	-21.386	0.000
	Moderate Risk	Deitch, J. R.,et al(2006)	0.023	0.019	0.028	-37.452	0.000
	Moderate Risk	Hwang, K.,et al(2019)	0.196	0.112	0.321	-4.188	0.000
	Moderate Risk	Gunasekaran, P.,et al(2018)	0.027	0.009	0.080	-6.139	0.000
	Moderate Risk	Giannotti, M.,et al(2010)	0.094	0.086	0.102	-45.433	0.000
	Moderate Risk	Nilsson, M.,et al(2013)	0.037	0.014	0.095	-6.394	0.000
	Moderate Risk	Humphrey, J. A. ,et al(2019)	0.062	0.046	0.083	-16.844	0.000
	Moderate Risk	Carson, J. D.,et al(1999)	0.014	0.001	0.187	-2.993	0.003
Random	Moderate Risk		0.053	0.028	0.101	-8.256	0.000

Figure 5: Forest plot of subgroup analysis for the prevalence of sports-related eye injuries in total sports injuries

three countries (Nigeria, India, and Pakistan) from the lower-middle-income category had addressed this issue. These groups of studies reported the mean age of patients with eye injuries but did not report the mean age of patients suffering from sports-related eye injuries. Due to the lack of reports on age, sex, and type of sports in these studies, no subgroup analysis was conducted in this group of studies.

Prevalence of sports-related eye injuries in total sports injuries

16,601 cases of sports injuries were reported in these studies, which eye injuries consisted 6.7% of them. Different sports can be divided into three categories based on the chance of the eye being hit hard enough to cause injury. Thus, different sports were analyzed in three categories of high, moderate, and low risk. The numbers of studies relating to moderate- and low-risk sports were approximately equal. There were more cases within high-risk sports, but there was no significant difference between the studies, which is probably due to the low number of the located studies.

Prevalence of sports-related eye injuries sorted by the type of injury

Different sports cause different eye injuries. Eye injuries are categorized into open globe injury (OGI), CGI, and adnexa injury. In OGI, the eye wall has a full-thickness wound, while in the GCI, the eye wall does not have a full-thickness wound. Adnexa injury is defined as the trauma of orbit, conjunctiva, and eyelids.[57]

Some of the included studies in the meta-analysis only examined one type of sports-related eye injuries, which were analyzed separately.

Twenty-five studies were included in these analyses, with the most studies about orbital fractures and the highest prevalence in orbital fractures and GCI. There were not enough studies in this subgroup; however, it is recommended that instead of reporting eye injuries of only one kind, standard categorizations of eye traumas be used for reporting eye injuries.

McGwin *et al*.[35] and Wong *et al*.[58] in the US reported that more than 10% of eye injuries in this country are related to sports. Saeed *et al*. in Ireland reported 517 cases of eye injuries, of which 54 were related to sports, consisting 10.44% of them.[59] These amounts are equal to the reported amount in this systematic review, which is justifiable because most of the included studies were conducted in high-income countries. However, Maurya *et al*.[60] in India reported 24%, which highlights the gravity of the situation in countries with lower incomes. Differences in reported values in different countries or even within one country can be because of the time of the report, the population of interest, and different settings, which

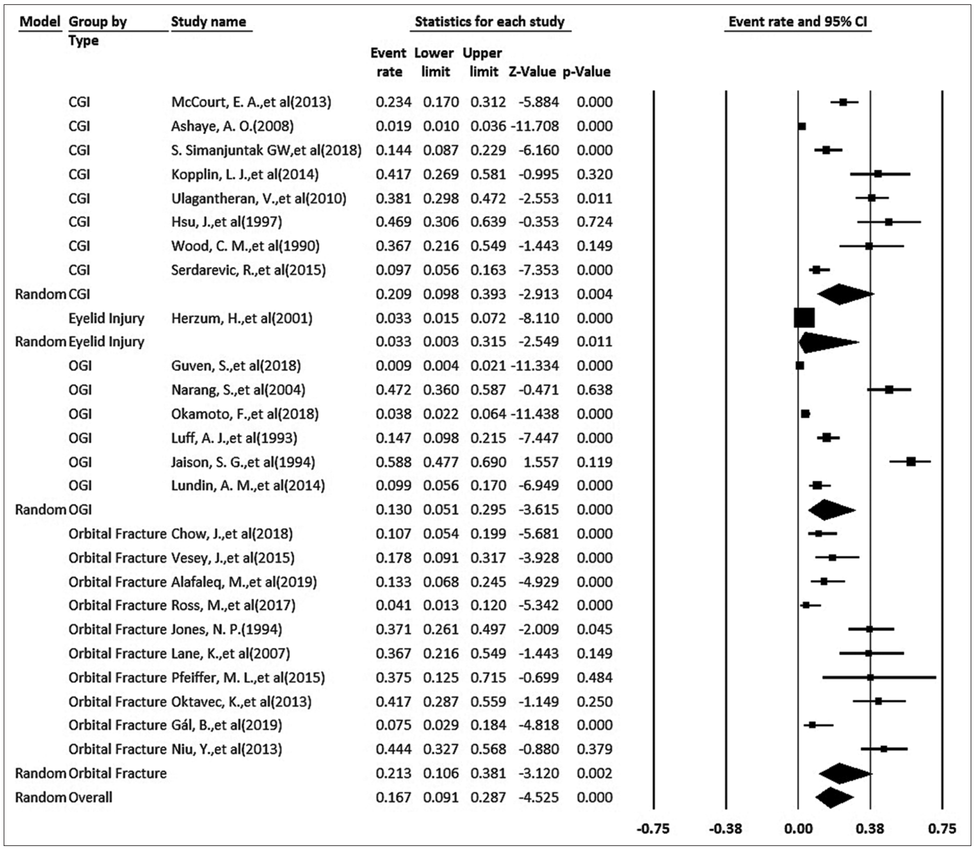


Figure 6: Forest plot of the prevalence of sports-related eye injuries in total eye injuries, sorted by the type of injury

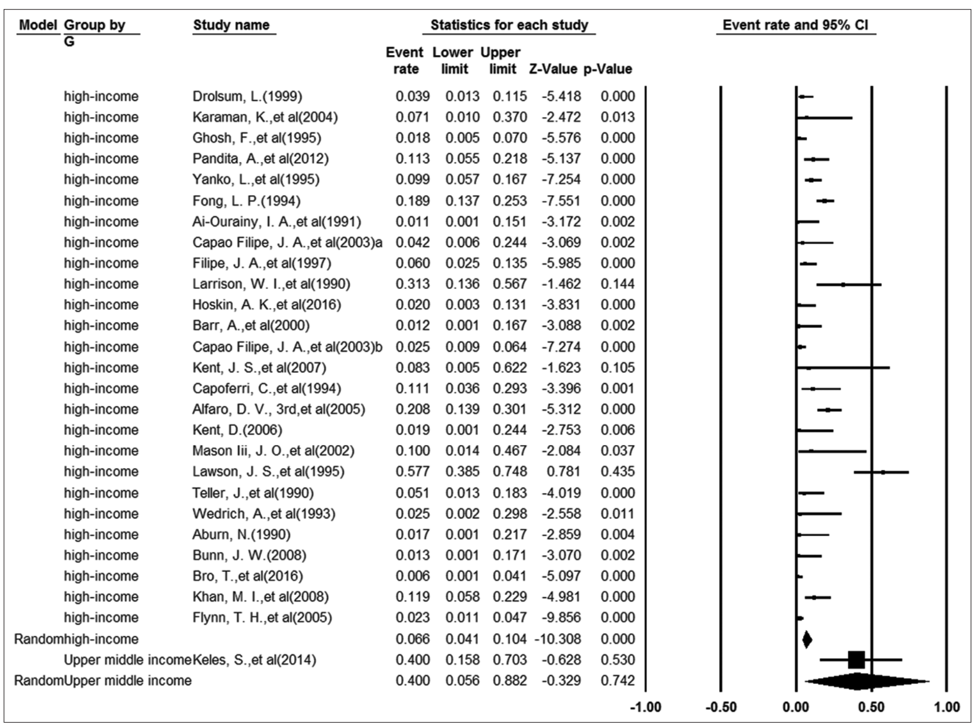


Figure 7: Prevalence of blindness in sports-related eye injuries sorted by country

should be taken into consideration when designing studies and reporting results.

By modifying the sport's rules and promoting safety measures, sports-related eye injuries and consequent visual impairments

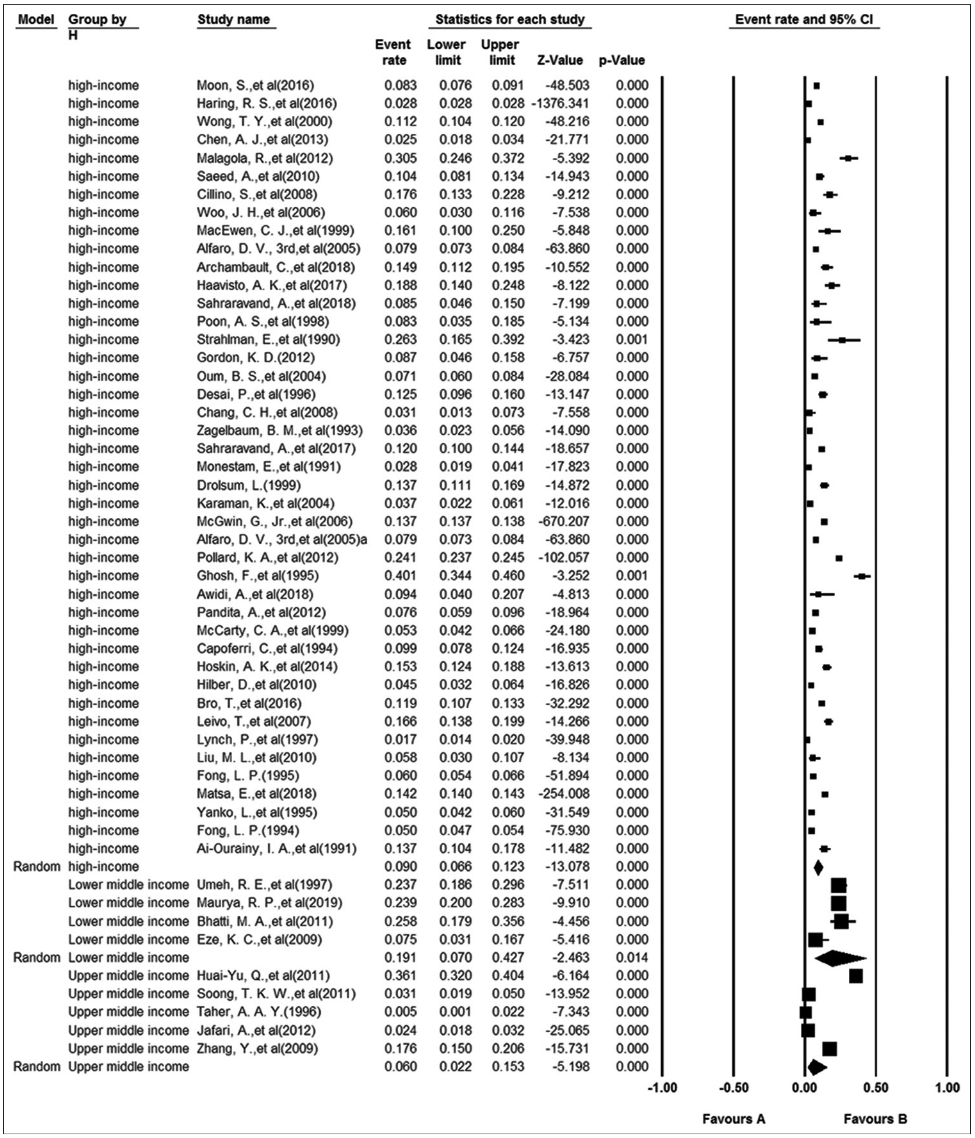


Figure 8: Forest plot for the prevalence of sports-related eye injuries in total eye injuries, sorted by country

and blindness can be prevented. These measures can also decrease the costs of treatment and rehabilitation. Therefore, strategies such as modifying the rules or using safety eye-wear are used. Safety glasses and masks that protect the face are also appropriate tools.

Conclusion

Findings of this study suggest that sport-related eye injuries constitute a major part of eye injuries and a considerable portion of these traumas lead to blindness.

Strengths and limitations

The strengths of this systematic review are the comprehensive search and the good quality of the included studies in the meta-analysis. This study will be a useful guide for future studies by identifying the defects of previous studies.

Limitations of this study are that most of the included studies were retrospective, and this caused some constrictions in data collection, assessing the injured person, and follow-up.

When an injured player is brought to the emergency unit, only major injuries will probably be recorded and minor injuries are dismissed, or in some cases because of other major injuries in the body, the whole eye injury may be overlooked.

Recommendations

It is recommended to conduct more specific studies, addressing age, sex, and type of sport separately to develop better planning for people at risk. Considering the lack of adequate studies in lower-income countries and lower-middle-income countries, conducting similar studies in these countries is very important.

Educational interventions can be beneficial by spreading information about the importance of using safety equipment. By modifying the sport's rules and promoting safety measures,

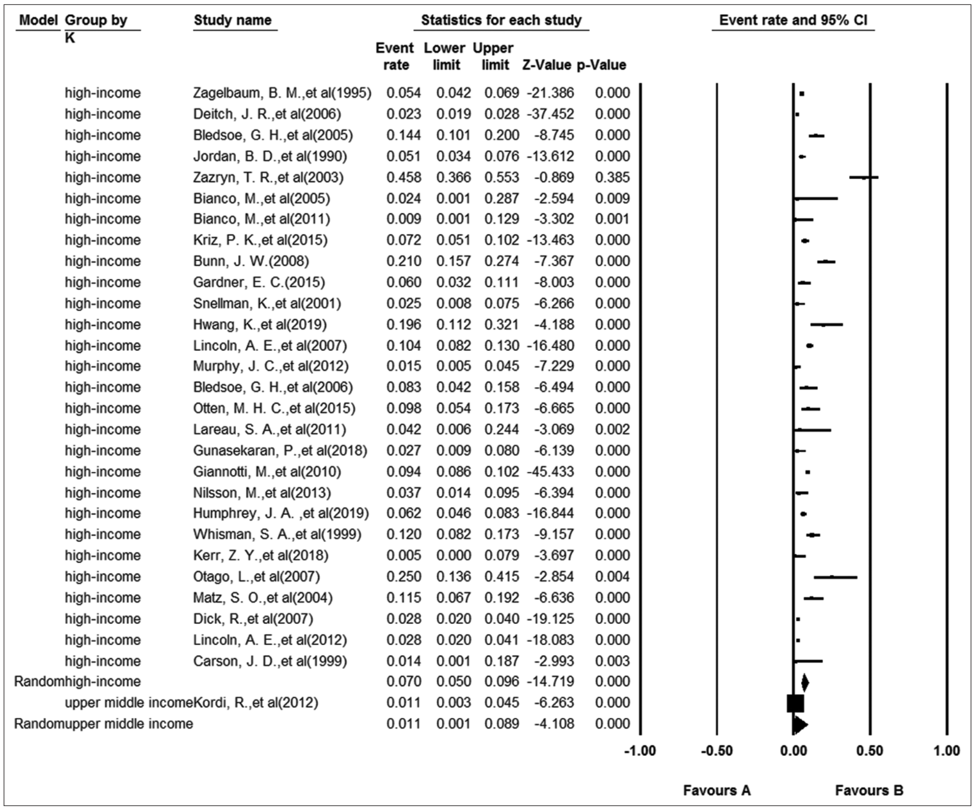


Figure 9: Prevalence of sports-related eye injuries in total sports injuries, sorted by country

Table 3: Descriptions of the included studies in the meta-analysis of the prevalence of sports-related eye injuries in total sports injuries

Author/year	Year	Country	Sports
Zagelbaum B. M. *et al.*	1995	US	Basketball
Deitch J. R. *et al.*	2006	US	Basketball
Bledsoe G. H. *et al.*	2005	US	Boxing
Jordan B. D. *et al.*	1990	US	Boxing
Zazryn T. R. *et al.*	2003	Australia	Boxing
Bianco M. *et al.*	2005	Italy	Boxing
Bianco M. *et al.*	2011	Italy	Boxing
Kriz P. K. *et al.*	2015	US	Field hockey
Bunn J. W.	2008	US	Field hockey
Gardner E. C.	2015	US	Field hockey
Snellman K. *et al.*	2001	Finland	Floor ball
Hwang K. *et al.*	2019	Korea	Handball
Lincoln A. E. *et al.*	2007	US	Lacrosse
Murphy J. C. *et al.*	2012	Ireland	Hurling
Bledsoe G. H. *et al.*	2006	US	MMA
Otten M. H. C. *et al.*	2015	US	MMA
Lareau S. A. *et al.*	2011	US	Mountain bike racing
Gunasekaran P. *et al.*	2018	Australia	Rugby
Giannotti M. *et al.*	2010	Canada	Soccer
Nilsson M. *et al.*	2013	Sweden	Soccer
Humphrey J. A. *et al.*	2019	UK	Tennis
Whisman S. A. *et al.*	1999	US	White water rafting
Kerr Z. Y. *et al.*	2018	US	Women's lacrosse
Otago L. *et al.*	2007	Australia	Women's lacrosse

Contd...

Table 3: Contd...

Author/year	Year	Country	Sports
Matz S. O. *et al*.	2004	US	Women's lacrosse
Dick R. *et al*.	2007	US	Women's lacrosse
Lincoln A. E. *et al*.	2012	US	Women's lacrosse
Carson J. D. *et al*.	1999	Canada	Women's rugby
Kordi R. *et al*.	2012	Iran	Wrestlers

Table 4: Descriptions of the studies included in the meta-analysis of the prevalence of sports-related injuries sorted by the type of injury

Author/year	Country	Type of injury	Total injuries	Sports injury
McCourt E. A. *et al*. (2013)	US	CGI	137	32
Ashaye A. O. (2008)	Nigeria	CGI	472	9
S. Simanjuntak G. W. *et al*. (2018)	Indonesia	CGI	97	14
Kopplin L. J. *et al*. (2014)	US	CGI	36	15
Ulagantheran V. *et al*. (2010)	Malaysia	CGI	118	45
Hsu J. *et al*. (1997)	US	CGI	32	15
Herzum H. *et al*. (2001)	Germany	Eyelid injury	180	6
Wood C. M. *et al*. (1990)	UK	Choroidal rupture	30	11
Guven S. *et al*. (2018)	Turkey	OGI	633	6
Narang S. *et al*. (2004)	India	OGI	72	34
Okamoto F. *et al*. (2018)	Japan	OGI	343	13
Chow J. *et al*. (2018)	Australia	Orbital fracture	75	8
Vesey J. *et al*. (2015)	UK	Orbital fracture	45	8
Alafaleq M. *et al*. (2019)	France	Orbital fracture	60	8
Ross M. *et al*. (2017)	Canada	Orbital fracture	73	3
Jones N. P. (1994)	UK	Orbital fracture	62	23
Lane K. *et al*. (2007)	US	Orbital fracture	30	11
Pfeiffer M. L. *et al*. (2015)	US	Orbital fracture	8	3
Oktavec K. *et al*. (2013)	US	Orbital fracture	48	20
Gál B. *et al*. (2019)	Czech republic	Orbital fracture	53	4
Niu Y. *et al*. (2013)	China	Orbital fracture	63	28
Luff A. J. *et al*. (1993)	UK	Perforating ocular injury	143	21
Jaison S. G. *et al*. (1994)	India	Perforating ocular injury	80	47
Serdarevic R. *et al*. (2015)	Bosnia	CGI	124	12
Lundin A. M. *et al*. (2014)	US	OGI	111	11

CGI: Closed globe injury, OGI: Open globe injury

Table 5: Categories of the sports in unprotected athletes based on the potential risk of eye injury

High-risk	Moderate-risk	Low-risk/eye safe
Air rifle/BB gun	Badminton	Swimming and Scuba diving
Paintball	Tennis	Skiing (on ice and water)
Baseball/Softball/Cricket	Volleyball	Biking
Basketball	Water polo	Noncontact martial arts
Lacrosse	Football	Wrestling
Fencing	Soccer	Track and field
Field hockey		Gymnastics
Ice hockey		
Squash/racquetball		
Boxing		
Full contact martial arts		

sports-related eye injuries and consequent visual impairments and blindness can be prevented.

Financial support and sponsorship

Nil.

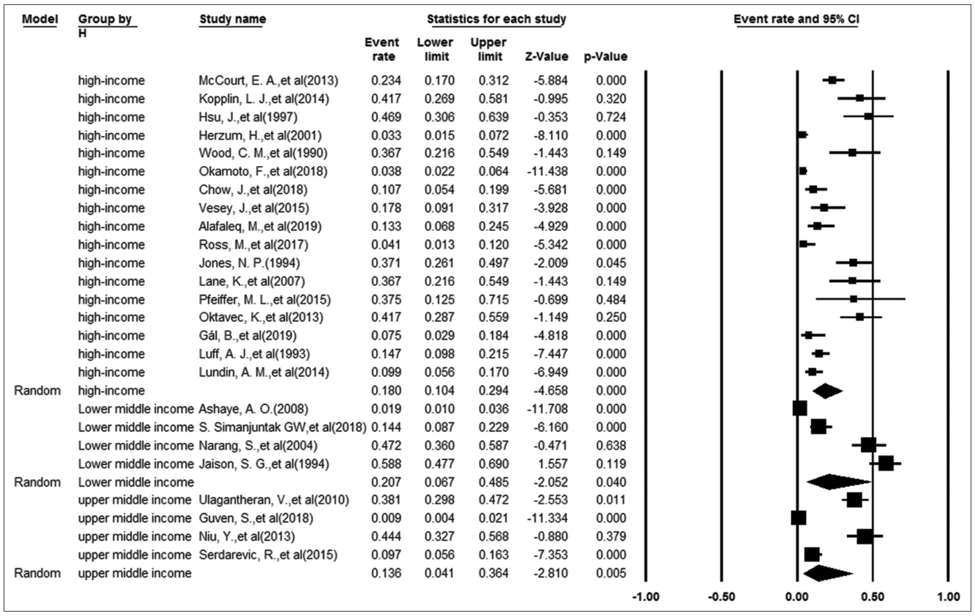


Figure 10: Forest plot for subgroup analysis of the prevalence of sports-related eye injuries in total eye injuries, sorted by the type of injury

Table 6: Results of subgroup analysis for the prevalence of sports-related eye injuries in total sports injuries sorted by the type of sports

Group	Estimated prevalence and 95% CI				Test of null (two-tailed)		Heterogeneity			
	Number of studies	Point estimate	Lower limit	Upper limit	*Z*	*P*	*Q*	df (Q)	*P*	*I*-squared
High risk	16	0.074	0.046	0.115	−10.067	<00.1	287.97	15.00	<00.1	94.79
Low risk	5	0.064	0.027	0.145	−5.796	<00.1	11.92	4.00	0.02	66.44
Moderate risk	8	0.053	0.028	0.101	−8.256	<00.1	198.62	7.00	<00.1	96.48

CI: Confidence interval

Table 7: Results of subgroup analysis for the prevalence of sports-related eye injuries in total eye injuries, sorted by the type of injury

Groups	Estimated prevalence and 95% CI				Test of null (two-tailed)		Heterogeneity			
	Number studies	Point estimate	Lower limit	Upper limit	*Z*	*P*	*Q*	df (Q)	*P*	*I*-squared
CGI	8	0.21	0.10	0.39	−2.91	<00.1	114.88	7	<00.1	93.91
Eyelid injury	1	0.03	<00.1	0.31	−2.55	0.01	0.00	0	1.00	0.00
OGI	6	0.13	0.05	0.30	−3.61	<00.1	203.02	5	<00.1	97.54
Orbital fracture	10	0.21	0.11	0.38	−3.12	<00.1	57.46	9	<00.1	84.34
Overall	25	0.22	0.20	0.24	−20.70	<00.1	408.83	24	<00.1	94.13

CGI: Closed globe injury, OGI: Open globe injury, CI: Confidence interval

Table 8: Prevalence of sports-related eye injuries in total eye injuries, sorted by country

Groups	Estimated prevalence and 95% CI				Test of null (two-tailed)		Heterogeneity			
	Number Studies	Point estimate	Lower limit	Upper limit	*Z*	*P*	*Q*	df (Q)	*P*	*I*-squared
High-income	43	0.0902	0.0655	0.1230	−13.07	<0.001	243,275.86	42	<0.001	99.98
Lower-middle income	4	0.1910	0.0696	0.4269	−2.46	0.0138	8.5576715	3	0.003	64.94
Upper-middle income	5	0.0600	0.0221	0.1527	−5.19	<0.001	406.10011	4	<0.001	99.01

CI: Confidence interval

Table 9: Results of subgroup analysis for the prevalence of sports-related eye injuries in total eye injuries, sorted by the type of injury

Groups	Estimated prevalence and 95% CI				Test of null (two-tailed)		Heterogeneity			
	Number Studies	Point estimate	Lower limit	Upper limit	*Z*	*P*	*Q*	df (Q)	*P*	*I*-squared
High-income	17	0.1803	0.1042	0.2938	−4.66	<00.1	151.71	16	<00.1	89.45
Lower-middle income	4	0.2066	0.0672	0.4850	−2.05	0.040	132.50	3	<00.1	97.74
Upper-middle income	4	0.1359	0.0415	0.3636	−2.81	0.005	111.21	3	<00.1	97.30

CI: Confidence interval

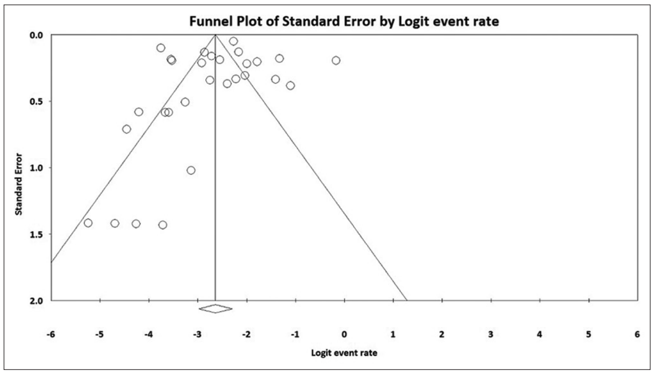


Figure 11: Funnel plot for assessing the publication bias

Conflicts of interest

There are no conflicts of interest.

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Appendix

Appendix 1

The Joanna Briggs Institute

Introduction

The Joanna Briggs Institute (JBI) is an international, membership-based research and development organization within the Faculty of Health Sciences at the University of Adelaide. The Institute specializes in promoting and supporting evidence-based healthcare by providing access to resources for professionals in nursing, midwifery, medicine, and allied health. With over 80 collaborating centers and entities servicing over 90 countries, the Institute is a recognized global leader in evidence-based healthcare.

Joanna Briggs Institute Systematic Reviews

The core of evidence synthesis is the systematic review of literature of a particular intervention, condition, or issue. The systematic review is essentially an analysis of the available literature (that is, evidence) and a judgment of the effectiveness or otherwise of a practice involving a series of complex steps. The JBI takes a particular view on what counts as evidence and the methods utilized to synthesize those different types of evidence. In line with this broader view of evidence, the Institute has developed theories, methodologies, and rigorous processes for the critical appraisal and synthesis of these diverse forms of evidence to aid in clinical decision-making in health care. There now exists JBI guidance for conducting reviews of effectiveness research, qualitative research, prevalence/incidence, etiology/risk, economic evaluations, text/opinion, diagnostic test accuracy, mixed-methods, umbrella reviews, and scoping reviews. Further information regarding JBI systematic reviews can be found in the JBI Reviewer's Manual on our website.

Joanna Briggs Institute Critical Appraisal Tools

All systematic reviews incorporate a process of critique or appraisal of the research evidence. The purpose of this appraisal is to assess the methodological quality of a study and to determine the extent to which a study has addressed the possibility of bias in its design, conduct, and analysis. All papers selected for inclusion in the systematic review (that is – those that meet the inclusion criteria described in the protocol) need to be subjected to rigorous appraisal by two critical appraisers. The results of this appraisal can then be used to inform synthesis and interpretation of the results of the study. JBI Critical Appraisal tools have been developed by the JBI and collaborators and approved by the JBI Scientific Committee following extensive peer review. Although designed for use in systematic reviews, JBI critical appraisal tools can also be used when creating Critically Appraised Topics, in journal clubs, and as an educational tool.

Joanna Briggs Institute Critical Appraisal Checklist for Studies Reporting Prevalence Data

Reviewer ______________________ Date ______________

Author ______________________ Year ______________ Record Number ________

	Yes	No	Unclear	Not applicable
Was the sample frame appropriate to address the target population?	□	□	□	□
Were study participants sampled in an appropriate way?	□	□	□	□
Was the sample size adequate?	□	□	□	□
Were the study subjects and the setting described in detail?	□	□	□	□
Was the data analysis conducted with sufficient coverage of the identified sample?	□	□	□	□
Were valid methods used for the identification of the condition?	□	□	□	□
Was the condition measured in a standard, reliable way for all participants?	□	□	□	□
Was there appropriate statistical analysis?	□	□	□	□
Was the response rate adequate, and if not, was the low response rate managed appropriately?	□	□	□	□

Overall appraisal: Include □ Exclude □ Seek further info □

Comments (Including reason for exclusion) ____________________

Joanna Briggs Institute Critical Appraisal Checklist for Studies Reporting Prevalence Data

How to cite: Munn Z, Moola S, Lisy K, Riitano D, Tufanaru C. Methodological guidance for systematic reviews of observational epidemiological studies reporting prevalence and incidence data. Int J Evid Based Healthc 2015;13 (3):147-53.

Answers: Yes, No, Unclear, or Not/Applicable

Was the sample frame appropriate to address the target population?

This question relies upon knowledge of the broader characteristics of the population of interest and the geographical area. If the study is of women with breast cancer, knowledge of at least the characteristics, demographics, and medical history is needed. The term "target population" should not be taken to infer every individual from everywhere or with similar disease or exposure characteristics. Instead, give consideration to specific population characteristics in the study, including age range, gender, morbidities, medications, and other potentially influential factors. For example, a sample frame may not be appropriate to address the target population if a certain group has been used (such as those working for one organization or one profession), and the results then inferred to the target population (i.e. working adults). A sample frame may be appropriate when it includes almost all the members of the target population (i.e. a census, or a complete list of participants, or complete registry data).

Were study participants recruited in an appropriate way?

Studies may report random sampling from a population, and the methods section should report how sampling was performed. Random probabilistic sampling from a defined subset of the population (sample frame) should be employed in most cases; however, random probabilistic sampling is not needed when everyone in the sampling frame will be included/analyzed. For example, reporting on all the data from a good census is appropriate as a good census will identify everybody. When using cluster sampling, such as a random sample of villages within a region, the methods need to be clearly stated as the precision of the final prevalence estimate incorporates the clustering effect. Convenience samples, such as a street survey or interviewing lots of people at public gatherings, are not considered to provide a representative sample of the base population.

Was the sample size adequate?

The larger the sample, the narrower will be the confidence interval around the prevalence estimate, making the results more precise. Adequate sample size is important to ensure good precision of the final estimate. Ideally, we are looking for evidence that the authors conducted a sample size calculation to determine adequate sample size. This will estimate how many subjects are needed to produce a reliable estimate of the measure (s) of interest. For conditions with a low prevalence, a larger sample size is needed. Further, consider sample sizes for subgroup (or characteristics) analyses and whether these are appropriate. Sometimes, the study will be large enough (as in large national surveys) whereby a sample size calculation is not required. In these cases, the sample size can be considered adequate.

When there is no sample size calculation, and it is not a large national survey, the reviewers may consider conducting their own sample size analysis using the following formula:[1,2]

$$n = \frac{Z^2 P(1-P)}{d^2}$$

Where:

n = sample size

Z = Z statistic for a level of confidence

P = Expected prevalence or proportion (in proportion of one; if 20%, $P = 0.2$)

d = Precision (in proportion of one; if 5%, $d = 0.05$)

Were the study subjects and setting described in detail?

Certain diseases or conditions vary in prevalence across different geographic regions and populations (e.g. women vs. men, sociodemographic variables between countries). The study sample should be described in sufficient detail so that other researchers can determine if it is comparable to the population of interest to them.

Was data analysis conducted with sufficient coverage of the identified sample?

Coverage bias can occur when not all subgroups of the identified sample respond at the same rate. For instance, you may have a very high response rate overall for your study, but the response rate for a certain subgroup (i.e. older adults) may be quite low.

Were valid methods used for the identification of the condition?

Here, we are looking for measurement or classification bias. Many health problems are not easily diagnosed or defined, and some measures may not be capable of including or excluding appropriate levels or stages of the health problem. If the outcomes were assessed based on existing definitions or diagnostic criteria, then the answer to this question is likely to be yes. If the outcomes were assessed using observer-reported or self-reported scales, the risk of over- or under-reporting is increased, and objectivity is compromised. Importantly, determine if the measurement tools used were validated instruments as this has a significant impact on outcome assessment validity.

Was the condition measured in a standard, reliable way for all participants?

Considerable judgment is required to determine the presence of some health outcomes. Having established the validity of the outcome measurement instrument (see item 6 of this scale), it is important to establish how the measurement was conducted. Were those involved in collecting data trained or educated in the use of the instrument/s? If there was more than one data collector, were they similar in terms of level of education, clinical or research experience, or level of responsibility in the piece of research being appraised? When there was more than one observer or collector, was there comparison of results from across the observers? Was the condition measured in the same way for all participants?

Was there appropriate statistical analysis?

Importantly, the numerator and denominator should be clearly reported, and percentages should be given with confidence intervals. The methods section should be detailed enough for reviewers to identify the analytical technique used and how specific variables were measured. In addition, it is also important to assess the appropriateness of the analytical strategy in terms of the assumptions associated with the approach as differing methods of analysis are based on differing assumptions about the data and how it will respond.

Was the response rate adequate, and if not, was the low response rate managed appropriately?

A large number of dropouts, refusals, or "not founds" among selected subjects may diminish a study's validity, as can low response rates for survey studies. The authors should clearly discuss the response rate and any reasons for non-response and compare persons in the study to those not in the study, particularly with regard to their sociodemographic characteristics. If reasons for non-response appear to be unrelated to the outcome measured and the characteristics of non-responders are comparable to those who do respond in the study (addressed in question 5, coverage bias), the researchers may be able to justify a more modest response rate.

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