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A systematic review of the worldwide prevalence of polio reported in 31 studies.

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ABSTRACT

Background Recent accurate prevalence rates estimating the number of polio survivors at any given time are not available. We aim to systematically review literature concerning the prevalence of polio worldwide.

Methods Electronic databases were searched up to May 2016 for peer reviewed studies including population-based approach with a defined denominator and some form of diagnostic or clinical verification of polio. Exclusion criteria were any prevalence data were unable to be extracted or calculated and studies reporting on incidence only. The quality of each included study was assessed using an existing tool modified for use in prevalence studies. Average crude prevalence rates were used to calculate worldwide estimates.

Results Thirty-one studies met criteria with 90% of studies conducted in low-to-lower middle income countries. Significant variability in the prevalence of polio was revealed, in low-to-lower middle income (15 per 100,000 in Nigeria to 1,733 in India) and upper-middle to high-income countries (24 (Japan) to 380 per 100,000 (Brazil). The total combined prevalence of polio for those studies at low to moderate risk of bias ranged from 165 (high-income countries) to 425 (low-to-lower middle income countries) per 100,000 person years. Lameness surveys of children predominated, with wide variation in case definition and assessment criteria.

Conclusions These results highlight the need for future epidemiological studies of polio to examine nationally representative samples, including all ages and more focus on high-income countries. Such efforts will improve capacity to provide reliable and more robust worldwide prevalence estimates.

Strengths and limitations of this study

- As the battle to eliminate new cases of polio continues, there are no accurate prevalence rates of polio available.
- This is the first study to systematically review studies undertaken examining the worldwide prevalence of polio.
- Results from this review show that studies to date, primarily based on lameness surveys, demonstrate significant variability in the prevalence of polio across low to high income countries. Few studies have examined nationally representative samples thus limiting the reliability of current prevalence estimates.
- While efforts were undertaken to identify and access all relevant article, it is likely that some studies were not identified by the search strategy.
- The estimates provided in this review are likely an underestimation of the prevalence of polio, but findings support the need for future studies examining nationally representative samples that are designed to reduce bias noted in this review.

INTRODUCTION

Poliomyelitis (polio) is a highly infectious, incurable viral disease that appeared in endemic form in 1900-1950[1] , caused by a wild or live vaccine-derived virus. Polio invades the central nervous system[2,3] and sequalae may include permanent physical disability (60-90%), and respiratory, heart and musculoskeletal diseases.[4] Up to 40% of survivors will experience post-polio syndrome, being new or worsening disabling symptoms 30-40 years after the original infection.[5] Efforts to eradicate polio with mass vaccination programs have led to reductions in confirmed cases[1], from an annual rate of approximately 50,000 in 1980 to <1,000 in 2001.[6] Estimates suggest that 12-20 million individuals are living with polio sequelae worldwide.[7] However, recent accurate prevalence rates estimating the number of polio survivors at any given time are not available.[8] Published international prevalence studies are problematic as they have (i) tended to focus on the initial disease and needs in the immediate aftermath, (ii) been inconsistent in the definition of "polio survivor," with it often unclear whether this refers all those infected or only those sustaining some form of residual disability, (iii) predominantly focused on health status rather than the everyday effects on people's lives, their needs, and those of their carers, iv) produced inconsistent findings on long-term outcomes, perhaps due to cultural differences, and/or been (vii) limited to lameness surveys of children in mostly low-to-lower middle income countries.[9] Cases of polio may also be missed as those affected may not attend hospital due to quarantine requirements. Worldwide, only 11% of those paralyzed by polio are thought to be captured by national surveillance systems.[10] Hence, regional prevalence estimates are often crude and

fragmentary. This systematic literature review aims to synthesise current knowledge on the prevalence of polio worldwide using all available population-based prevalence studies.

METHODS

This review is reported according to the PRISMA Statement.

Search strategy

We searched Medline, CINAHL, Psychology and behavioral sciences, ProQuest, Scopus, and Web of Science from inception to May 2016 for relevant studies. A search strategy was developed for Medline using 'post-polio syndrome', 'poliovirus', 'polio', 'postpolio', 'poliomyelitis', 'postpoliomyelitis', 'PPMA', 'PPMD', 'LEOP', or 'late effects of polio' and 'epidemiol', 'rate', 'proportion', or 'prevalence*', and was then adapted for other database searches. Hand searching of included articles was also undertaken.

Inclusion/exclusion criteria

Inclusion criteria were: peer reviewed; written in English; reporting of prevalence of polio; use of a population-based, epidemiology approach with a defined denominator; and some form of diagnostic or clinical verification of polio. Only those studies reporting on cases ascertained from a general population sample (i.e., not restricted by gender or ethnicity) were included to enable comparison between populations, and with other conditions, and to enhance representativeness of the findings. Studies in which any prevalence data were unable to be extracted or calculated, or studies reporting incidence data only were excluded. Duplicate publications reporting on the same research data were also removed.

Quality appraisal

Each study was assessed for methodological quality and risk of bias using a 10-item assessment tool (external (4 items) and internal (6 items) validity) specifically designed for population-based prevalence studies. Further, a summary assessment evaluates the overall risk

of study bias based on the 10 items.[1] A summary assessment deeming a study to be at low risk of bias suggests that 'further research is very unlikely to change our confidence in the estimate'. A moderate risk of bias rating suggests that 'further research is likely to have an important impact on our confidence in the estimate and may change the estimate'. The limitations of studies considered to be at high risk of bias suggest that 'further research is very likely to have an important impact on our confidence in the estimate and is likely to change the estimate'. For this review, a study was considered to have a high risk of bias if the target population was not closely representative of the national population, if there was no use of random selection, and if the study had a more than a minimal risk of non-response bias.

Data extraction and synthesis

Two authors (KJ, SB) independently reviewed abstracts for possible inclusion. In cases of non-consensus, a third independent review was obtained from a third author (VF). Any on-going discrepancies were resolved via discussion. In cases of incomprehensive study methodology, authors were approached to determine a study's potential inclusion. Where possible, copies of full articles were obtained for studies meeting the inclusion criteria. Reviewers extracted standard information per study on study characteristics, target population, research design, and verification of polio diagnosis. Only those studies considered to be at low to moderate risk of bias were included in the calculation of prevalence estimates. An average prevalence of polio is reported for each study as the number of cases per 100,000 people of all ages or a particular age range, depending on the data available. Rates were checked for accuracy where possible, depending on the data provided. Due to a lack of availability of standardized rates, prevalence rates are reported as crude estimate (i.e. unadjusted rates). Studies reporting adjusted values only have not been included the average prevalence calculation. In instances where a range of prevalence rates have been reported in a study and no overall rate reported (e.g. across ethnic groups or

different geographical regions or years), we have used the average of this range for the purposes of calculating an overall average prevalence. The research protocol was not subject to ethical approval as no such approval was required according to local regulations.

RESULTS

Included studies

An overview of the study selection process is outlined in Figure 1. The initial search yielded 1,239 citations. Following scanning of the titles for appropriateness for inclusion, those not meeting criteria and duplicate citations were removed (973). Where available, the abstracts of the remaining 266 potentially relevant titles identified across all sources (EBSCO n = 25; ProQuest n = 17; Scopus n = 88; Web of Science n = 136) were obtained. Following the availability and review of 206 abstracts, 117 full articles were independently evaluated for inclusion by two reviewers (SB, KJ). This process led to the elimination of 86 studies that did not meet the required inclusion criteria. The remaining 31 articles met inclusion criteria and were included in the review.

[INSERT FIGURE 1 ABOUT HERE]

The 31 eligible population-based studies reported data from 14 different countries. Data on polio prevalence in low-to-lower middle income countries were reported in 28 (90%) studies in 11 countries: India (14 studies); Nigeria (2 studies); Ethiopia (4 studies), and one study in each of the following locations: Indonesia, Ghana, Bangladesh, Niger, Cameroon, Sudan, Yemen, and Papua New Guinea. Population-based data on polio prevalence in upper-middle to high-income countries were available from 3 studies in 3 countries: Japan; Sweden; and Brazil.

Study characteristics

Table 1 provides a summary of the characteristics of those articles included in the review, including details of polio verification, population status, study design, and risk of bias. The included studies reported on polio prevalence data collected between 1974 and 2004. In terms of methodologies implemented across the included studies, diagnosis of polio was verified in 28 (90%) cases via the use of clinical investigations (i.e., examination by a physician or similar). Two of these studies also used laboratory investigations (i.e., virological confirmation) to confirm a history of polio. Twenty-nine (94%) of studies presented data collected by lameness surveys. These included surveys of schools (5), villages (1), families (1), house-to-house surveys (16), or a mixture there of (4), and postal questionnaires (1). One lameness survey examined a national population. The remaining two studies (6%) used multiple sources of case ascertainment. Studies most commonly examined urban/rural or semi-rural populations (12), with 8 eight studies limited to rural populations. Only one study reported a specific focus on an urban population. Of the 31 studies included, 26 (84%) presented data based on children and young persons aged <20 years. In terms of risk of bias, the majority of studies (77%) were at moderate (14 studies, 45%) to high (10 studies, 32%) risk of bias (Figure 2). Seven studies (23%) were considered to be at low risk of bias.

[INSERT TABLE 1 ABOUT HERE]

[INSERT FIGURE 2 ABOUT HERE]

Polio prevalence

In the general population, crude average prevalence in across all included studies ranged from 15 per 100,000 in Nigeria to 1,733 in Ajmer City, India (Figure 3). Among all low-to-lower middle income countries, crude rates of polio prevalence ranged from 15 per 100,000 (Igbo-

Ora, Nigeria) to 1,733 per 100,000 (Ajmer City, Rajasthan, India). Among all high-income counties, crude rates of polio prevalence ranged from 24 (PPS) per 100,000 (Japan) to 380 per 100,000 (Brazil). For those studies considered to be at low to moderate risk of bias, prevalence estimates ranged from 92 in Sweden to 730 in Ethiopia. The total combined prevalence of polio for those studies at low to moderate risk of bias ranged from 165 (high-income countries) to 425 (low-to-lower middle income countries) per 100,000 person years.

[INSERT FIGURE 3 ABOUT HERE]

DISCUSSION

This study reviews all the available data from population-based polio prevalence studies. Findings reveal significant discrepancies in average crude unadjusted prevalence rates, both between and within countries. Across all included studies and within low-to-lower middle income countries, prevalence rates ranged from 15 per 100,000 person-years in Igbo-Ora Nigeria to 1,733 in Ajmer City, India. Within high income countries, rates ranged from 24 in Japan to 380 in Brazil. Variations in prevalence between studies could be due to methodological variations and shortcomings.

Prevalence studies to date have predominantly used lameness surveys and varying clinical examinations or definitions to confirm a history of polio. Both of these approaches are problematic. Lameness surveys are limited in that they only capture those individuals with residual physical disabilities. Cases of people living with the effects of polio may be missed in the absence of any physical abnormality. There has also been a predominant focus on surveys of children living with the physical consequences of polio. Findings from such surveys are further limited by the considerable variation in the range of age groups that have been surveyed (i.e., 5-15 years, 0-6 months). Lameness surveys limited to the study of children with physical ailments are likely to represent an underestimate of the true prevalence

of those living post-polio. Few studies examined the prevalence of polio across all age groups, nor have samples that are representative of the respective national population been studied to inform appropriate gender, age and ethnicity estimates.

Worldwide variations in prevalence ratings could also be attributed to the diversity (and at times a lack of clarity) of applied case definitions and assessment processes to determine a history of polio. For example, while the majority of studies used lameness surveys, some studies were limited to the examination of lower extremity disabilities. Other studies included the examination of upper extremity disabilities in their efforts to identify those affected by polio. Three studies were limited to the examination of post-polio syndrome. Such inconsistencies are of concern given incomplete case ascertainment or disease misclassification can significantly skew the reported prevalence. Even assuming that all cases were ascertained in a given study, data would still omit those survivors of polio who are free from any observable, physical ailments. The estimates provided should be considered to be an underestimation of the prevalence of polio worldwide. Our findings suggest the average crude worldwide prevalence of 295/100,000 person years. However, given estimates that 10 to 40% of polio survivors are free from permanent physical disability[4], it is worth noting that the actual worldwide prevalence may be higher given the predominant focus to date on children and lame populations.

Furthermore, the majority of research to date has been conducted within low-to-lower middle income countries. Few studies have examined the prevalence of polio survivors in high income countries, including those declared to be polio-free. For example, no prevalence population-based studies were found based on data from Australasia, United Kingdom, or the United States of America. Hence, there is currently little suitable evidence available to inform the calculation of prevalence estimates for polio in high income countries.

This review has provided an overview of the worldwide prevalence of polio informed by population-based studies to date. While all efforts were undertaken to identify and access all articles relevant to the review, it is important to acknowledge the likelihood that some studies (i.e., unpublished or inaccessible studies) were not identified by the search strategy and therefore excluded. Alongside methodological concerns already discussed above, the international prevalence estimates from this review should be considered to be a likely underestimate of the true prevalence on an international scale. Well-designed epidemiological studies are now required to more accurately determine the prevalence of polio.

Future epidemiological polio studies must be designed to reduce bias noted in this review, including the use of random or cluster sampling, the examination of populations that are representative of the national population where possible, and the application of clear case definitions and diagnosis. In addition to recommending that future studies to adhere to the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) Statement[42], we offer specific recommendations for the pursuit of future studies examining prevalence of polio in Table 2.

[INSERT TABLE 2 ABOUT HERE]

Table 2. Suggested recommendations for future epidemiological studies of polio.

External validity
Examine nationally representative populations to enhance the generalizability of findings
Further prevalence studies are required in high-income countries
Examine all age groups (i.e., adults and children)
Estimate prevalence by age, sex, residency (urban/rural) and ethnic-specific rates
Undertake a census OR use some form of random selection (i.e., cluster sampling)
Extending findings of lameness surveys by also capturing lame-free cases of polio (i.e., using multiple sources of case ascertainment including review of medical records)
Use an established risk of bias tool specifically designed for use in population-based studies
Internal validity
Standard case definition and clinical evaluation
Describe any efforts to address potential sources of bias
Appropriate numerator (s) and denominator (s)

Conclusions

In conclusion, the review reported prevalence of polio worldwide from all identified studies. The majority of research to date has been limited to the examination of children and adolescents in low to lower middle income countries (predominantly India) who reside in geographical regions that are not representative of the national population (in terms of age,

sex, ethnic distributions, for example). Further research of polio prevalence is required using a population-based approach, examining nationally representative samples of all ages, particularly in high income countries, including those declared to be polio-free. Such efforts will reduce risks for sampling and measurement bias and improve capacity to provide reliable and more robust worldwide prevalence estimates.

Competing Interests None declared.

Disclosure of conflict of interest There are no conflicts of interest.

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Legends

Figure 1. Flow diagram of included/excluded studies.

Figure 2. Risk of bias summary of included population-based studies in reverse chronological order.

Figure 3. Polio prevalence by country income level.

What is already known on this subject?

The World Health Assembly commitment to the worldwide eradication of polio has achieved great success in the Americas, Europe and the Western Pacific. Yet, elimination of new polio cases is not complete. While estimates suggest that up to 20 million people live with the disabling consequences of polio, no accurate prevalence rates are available.

What this study adds?

This is the first study to systematically review studies examining the worldwide prevalence of polio. Our findings show that studies to date, primarily based on lameness surveys, demonstrate significant variability in the prevalence of polio across low to high income

countries. Few studies have examined nationally representative samples thus limiting the reliability of current worldwide prevalence estimates.

Contributorship statement

GJ conceived on the study. SB conducted searches and extracted the data. KJ and SB compiled and analyzed data. VF, AT and GJ advised throughout the study. KJ prepared the initial draft of the manuscript. All authors provided conceptual input and critical review of drafts.

Data sharing statement

No additional data available.

REFERENCES

1. Hoy D, Brooks P, Woolf A, et al. Assessing risk of bias in prtevalence studies: Modification of an existing tool and evidence of interrater agreement. *J Clin Epidemiol* 2012;**65**(934-939)

2. Nathanson N. The pathogenesis of poliomyelitis: what we don't know. *Adv Virus Res* 2008;**71**:1-50

3. Knipe D, Peter M. Enteroviruses: Polioviruses, coxsackieviruses, echoviruses, and newer enteroviruses. In: Fields BN, ed. Fields Virology. Philadelphia, PA: Wolters Kluwer, 2007:841-93.

4. Kang J-H, Li H-C. Comorbidity profile of poliomyelitis survivors in a Chinese population: a population-based study. *J Neurol Neurophysiol* 2011;**258**(6):1026-33

5. Lin KH, Lim YW. Post-poliomyelitis syndrome: case report and review of the literature. *Ann Acad Med Singapore* 2005;**34**(7):447-49

6. World Health Assembly. Polio Eradication by the Year 2000. Geneva, Switzerland: World Health Organization, 1988.

7. Gonzalez H, Olsson T, Borg K. Management of postpolio syndrome. *Lancet Neurol* 2010;**9**(6):634 e42

8. Grocea NE, Banks LM, Steinc MA. Surviving polio in a post-polio world. *Soc Sci Med* 2014;**107**:171-78 doi: 10.1016/j.socscimed.2014.02.024[published Online First: 14 February 2014]|.

9. Jones K, Theadom A, Ballala S, et al. Prevalence of polio: An international systematic review. Auckland, New Zealand: Auckland University of Technology, 2016.

10. Ward NA, Milstien JB, Hull HF, et al. The WHO-EPI initiative for the global eradication of poliomyelitis. *Biologicals* 1993;**21**(4):327-33

11. Takemura J, Saeki S, Hachisuka K, et al. Prevalence of post-polio syndrome based on a cross-sectional survey in Kitakyushu, Japan. *J Rehabil Med* 2004;**36**(1):1-3

12. Tessema T, Hailu A. Epidemiology of poliomyelitis in northwestern Ethiopia. *East Afr Med J* 2001;**78**(8):430-2

13. Anand K, Kant S, Kumar G, et al. Thirty year trend (1967-1996) in prevalence of poliomyelitis and vaccine coverage in Ballabgarh, Haryana, India. *J Epidemiol Community Health* 1998;**52**(12):823-25

14. Srinivasa DK, Sahai A, Rotti SB, et al. Poliomyelitis trends in Pondicherry, South India, 1989-91. *J Epidemiol Community Health* 1997;**51**(4):443-8

15. Ahlström G, Gunnarsson LG, Leissner P, et al. Epidemiology of Neuromuscular Diseases, Including the Postpolio Sequelae, in a Swedish County. *Neuroepidemiology* 1993;**12**(5):262-69

16. Soudarssanane MB, Rotti SB, Srinivasa DK, et al. Paralytic poliomyelitis in children under 6 years in Pondicherry: a community survey. *J Epidemiol Community Health* 1993;**47**(3):210-14 doi: 10.1136/jech.47.3.210.

17. Kumar R, Kumar V. Poliomyelitis control by annual immunization campaigns with oral polio-virus vaccine in a rural area of India. *Trop Geogr Med* 1991;**43**(1-2):215-9

18. Balraj V, John JT, Thomas M, et al. Efficacy of Oral Poliovirus Vaccine in Rural Communities of North Arcot District, India. *Int J Epidemiol* 1990;**19**(3):711-14 doi: 10.1093/ije/19.3.711.

19. Mehra M, Bansal Y. Prevalence of paralytic poliomyelitis in a rural and urban community of Delhi. *Indian Pediatr* 1990;**27**(9):915-7

20. Parakoyi B, Babaniyi OA. Prevalence of paralytic poliomyelitis in children of Kwara State, Nigeria: report of a house-to-house survey. *East Afr Med J* 1990;**67**(8):545-9

21. Tekle-Haimanot R, Abebe M, Gebre-Mariam A, et al. Community-based study of neurological disorders in rural central Ethiopia. *Neuroepidemiology* 1990;**9**(5):263-77

22. Khajuria R, Datta N, Kumar R, et al. Impact of annual immunisation programme with oral polio vaccine on the prevalence of paralytic poliomyelitis. *Indian J Pediatr* 1989;**56**(3):343-7

23. Dekker PA, Green-Abate C. Prevalence of residual paralysis due to poliomyelitis in schoolchildren in Addis Ababa. *Ethiop Med J* 1988;**26**(3):133-8

24. Maru M, Getahun A, Hoshna S. Prevalence of paralytic poliomyelitis in rural and urban populations in Ethiopia: report of a house-to-house survey. *Am J Trop Med Hyg* 1988;**38**(3):633-5

25. Osuntokun BO, Adeuja AOG, Schoenberg BS, et al. Neurological disorders in Nigerian Africians: A community-based study. *Acta Neurol (Napoli)* 1987;**75**(1):13-21

26. Tidke RW, Joshi U, Patel RB. Paralytic poliomyelitis in slums of Bombay. *Indian J Pediatr* 1986;**53**(1):109-13 doi: 10.1007/bf02787081.

27. Broca JS, Chaturvedi SK, Mathur GM. Prevalence of residual polio paralysis in children of 5-15 years age group in Ajmer City. *Indian J Public Health* 1985;**29**(3):193-200

28. Basu Rf, Sokhey J. Prevalence of poliomyelitis in India. *Indian J Pediatr* 1984;**51**(5):515-19 doi: 10.1007/bf02776613.

29. Heymann DL, Floyd VD, Lichnevski M, et al. Estimation of incidence of poliomyelitis by three survey methods in different regions of the United Republic of Cameroon. *Bull World Health Organ* 1983;**61**(3):501-07

30. Olive JM, Gadir A, Abbas M. Prevalence of residual paralysis from paralytic poliomyelitis in some urban and semi-rural areas of the Sudan, November 1982. *J Trop Pediatr* 1984;**30**(6):329-33

31. Srilatha V, Mukarji D, John TJ. The Prevalence of Poliomyelitis in Rural School Children in South India. *J Trop Pediatr* 1984;**30**(2):68-69 doi: 10.1093/tropej/30.2.68.

32. Hajar M, Zeid A, Saif M, et al. Prevalence, incidence, and epidemiological features of poliomyelitis in the Yemen Arab Republic. *Bull World Health Organ* 1983;**61**(2):353

33. Sabin AB, Silva E. Residual paralytic poliomyelitis in a tropical region of Brazil, 1969–1977: prevalence surveys in different age groups as indicators of changing incidence. *Am J Epidemiol* 1983;**117**(2):193-200

34. Hall AJ. A survey of lameness in school children in Gulf Province. *P N G Med J* 1982;**25**(1):26-8

35. Rotti SB, Satpathy SK, Mehta SP. Prevalence of paralytic poliomyelitis in Pondicherry, South India. *J Epidemiol Community Health* 1982;**36**(4):279-81 doi: 10.1136/jech.36.4.279.

36. Thuriaux MC. A prevalence survey of lower limb motor disorders in school-age children in Niger and an estimation of poliomyelitis incidence. *Trop Geogr Med* 1982;**34**(2):163-8

37. Snyder JD, Black RE, Baqui AH, et al. Prevalence of residual paralysis from paralytic poliomyelitis in a rural population of Bangladesh. *Am J Trop Med Hyg* 1981;**30**(2):426-30

38. Ulfah NM, Parastho S, Sadjimin T, et al. Polio and Lameness in Yogyakarta, Indonesia. *Int J Epidemiol* 1981;**10**(2):171-75 doi: 10.1093/ije/10.2.171|.

39. Jhala CI, Goel RK, Dave SK. Epidemiology of poliomyelitis in rural area of Gujarat -- a report of house to house survey in Patan Taluka. *Indian J Med Sci* 1979;**33**(6):143-9

40. Nicholas DD, Kratzer JH, Ofosu-Amaah S, et al. Outside Europe. Is poliomyelitis a serious problem in developing countries?--the Danfa experience. *BMJ*

1977;**1**(6067):1009-12 doi: 10.1136/bmj.1.6067.1009[published Online First: 16 April 1977]|.

41. Hardas U, Waikar A. Pilot survey of disabled children in and around Nagpur. *Indian J Pediatr* 1974;**41**(8):267-71 doi: 10.1007/bf02829306.

42. von Elm E, Altman DG, Egger M, et al. The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) Statement: Guidelines for Reporting Observational Studies. *Ann Intern Med* 2007;**147**(8):573-77 doi: http://dx.doi.org/10.7326/0003-4819-147-8-200710160-00010-w1.

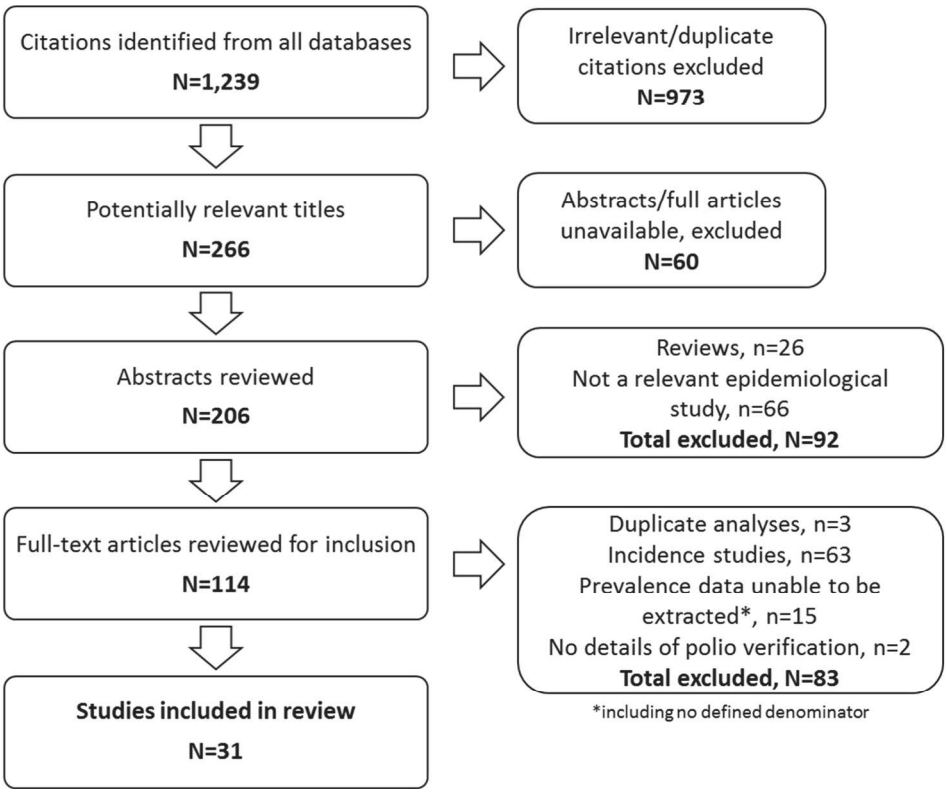

Figure 1. Flow diagram of included/excluded studies.

183x161mm (300 x 300 DPI)

	Target population close representation of national	Sampling frame true representation of target population	Random selection used	Minimal risk of non-response bias	Data collected from subjects (not a proxy)	Acceptable case definition	Reliable and validity measurement of parameter of	Consistent mode of data collection	Appropriate prevalence period	Appropriate numerators and denominators	Overall risk
Takemura 2004	✗	✓	✓	✗	✓	✓	✗	✓	✓	✓	Moderate
Tessema 2001	✗	✓	✓	✗	✓	✓	✓	✓	✓	✓	Low
Anand 1998	✗	✗	✗	✗	✓	✓	✓	✓	✓	✓	High
Srinivasa 1997	✗	✓	✗	✗	✓	✓	✓	✓	✓	✓	Moderate
Ahlstrom 1993	✓	✓	✓	✗	✗	✓	✓	✓	✓	✓	Low
Soudarssane 1993	✗	✓	✓	✗	✓	✓	✓	✓	✓	✓	Low
Kumar 1991	✗	✗	✗	✗	✗	✗	✓	✓	✓	✓	High
Balraj 1990	✗	✓	✓	✗	✓	✓	✗	✓	✓	✓	Moderate
Mehra 1990	✗	✓	✗	✗	✓	✓	✓	✓	✓	✓	Moderate
Parakoyi 1990	✗	✓	✓	✗	✓	✓	✓	✓	✓	✓	Low
Tekle-Haimanot 1990	✗	✓	✓	✓	✓	✗	✗	✓	✓	✓	Moderate
Khajuria 1989	✗	✗	✗	✗	✗	✓	✗	✗	✓	✓	High
Maru 1988	✗	✓	✓	✗	✓	✓	✓	✓	✓	✓	Low
Osuntokun 1987	✗	✓	✓	✗	✓	✗	✗	✓	✓	✓	Moderate
Tidke 1986	✗	✗	✗	✗	✓	✓	✓	✓	✓	✓	High
Broca 1985	✗	✓	✓	✗	✓	✓	✗	✓	✓	✓	Moderate
Basu 1984	✓	✓	✓	✗	✓	✗	✓	✓	✓	✓	Low
Olive 1984	✗	✓	✓	✗	✓	✗	✓	✓	✓	✓	Moderate
Srilatha 1984	✗	✓	✗	✗	✓	✗	✓	✓	✓	✓	High
Hajar 1983	✓	✓	✓	✗	✓	✓	✓	✓	✓	✓	Low
Heymann 1983	✗	✓	✓	✗	✓	✓	✓	✗	✓	✓	Moderate
Sabin 1983	✗	✓	✗	✗	✓	✓	✓	✓	✓	✓	Moderate
Dekker 1982	✗	✗	✗	✗	✓	✗	✗	✓	✓	✓	High
Hall 1982	✗	✓	✗	✗	✗	✓	✗	✗	✓	✓	High
Rotti 1982	✗	✓	✗	✗	✓	✓	✓	✓	✓	✓	Moderate
Thuriaux 1982	✗	✓	✓	✗	✓	✓	✗	✓	✓	✓	Moderate
Snyder 1981	✗	✓	✗	✗	✓	✓	✓	✓	✓	✓	Moderate
Ulfah 1981	✗	✗	✗	✗	✓	✓	✓	✗	✓	✓	High
Nicholas 1977	✗	✗	✗	✗	✗	✓	✓	✗	✓	✓	High
Hardas 1974	✗	✓	✓	✗	✓	✗	✓	✓	✓	✓	Moderate
Jhala 1973	✗	✗	✗	✗	✓	✓	✓	✓	✓	✓	High

Figure 2. Risk of bias summary of included population-based studies in reverse chronological order.

168x233mm (300 x 300 DPI)

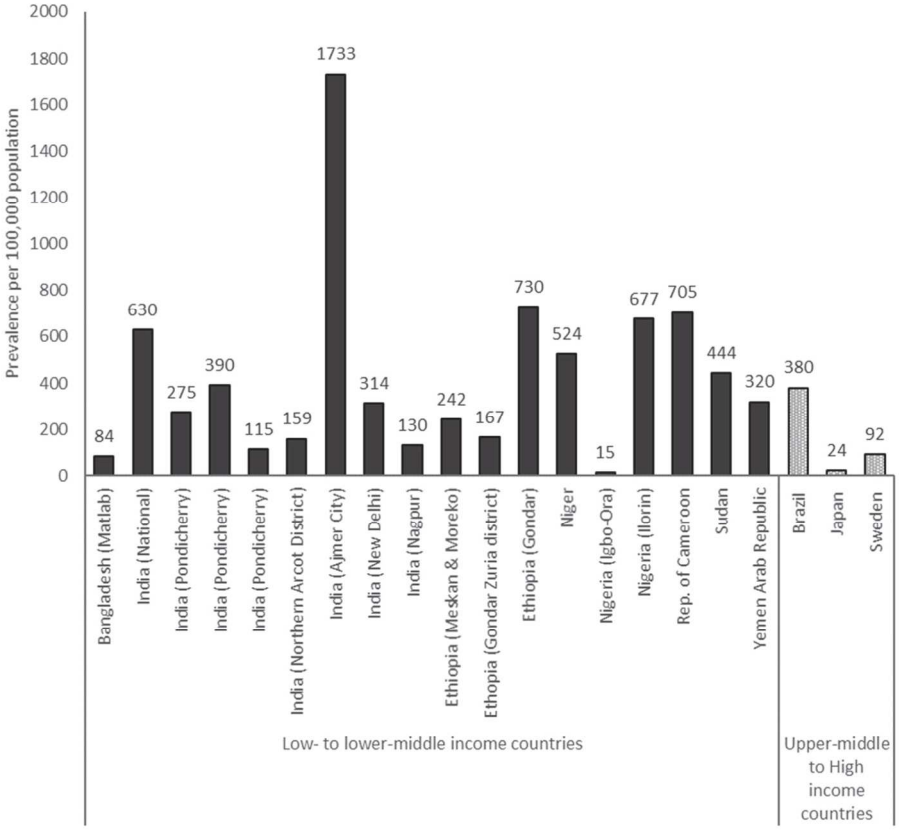

Figure 3. Polio prevalence by country income level

168x162mm (300 x 300 DPI)

Table 1. Details of included population-based studies in reverse chronological order.

First Author	Year	Country (Region)	Population status	Population base	Study design / Date	Full article	Verification of diagnosis	Risk rating
Takemura(11)	2004	Japan (Kitakyushu)	Registry of 13,000 physically disabled persons	342	Lameness survey (postal questionnaire)	Yes	Clinical investigation	Moderate
Tessema(12)	2001	Ethiopia* (Gondar Zuria district)	General population (urban/rural)	12,000 children aged 1-15 years	Lameness survey (house-to-house) Jul-Aug 1993	Yes	Clinical investigation	Low
Anand(13)	1998	India* (Ballabgarh, Haryana)	General population (rural)	28,464 children aged <15 years	Lameness survey (house-to-house) Dec 1996	Yes	Clinical and laboratory investigation	High
Srinivasa(14)	1997	India* (Pondicherry)	General population (urban/rural)	Approx. 11,000 children aged <60 months	Lameness survey (house-to-house) Jan-Feb of each year between 1989-91	Yes	Clinical investigation	Moderate
Ahlstrom(15)	1993	Sweden (Orebro)	General population (urban/rural)	269,341	Multiple sources (hospital, outpatient, institutional, insurance, medical records) 01 Jan 1988	Yes	Search of clinical records	Low
Soudarssane(16)	1993	India* (Pondicherry)	General population	47,960 children aged 0-6 years	Lameness survey (house-to-house) Apr-Jul 1989	Yes	Clinical investigation	Low
Kumar(17)	1991	India* (Ambala, Haryana State)	General population	15,761 children aged <15 years	Lameness survey (house-to-house) Jan 1989	Yes	Clinical investigation	High
Balraj(18)	1990	India* (Northern	General population	42,045 children aged <5 years	Lameness survey (house-to-house)	Yes	Clinical investigation	Moderate

First Author	Year	Country (Region)	Population status	Population base	Study design / Date	Full article	Verification of diagnosis	Risk rating
		Arcot District, Tamil Nadu State)	(rural)		Feb-Oct 1988			
Mehra(19)	1990	India* (New Delhi)	General population (urban/rural)	7,318 children aged 5-15 years	Lameness survey (house-to-house) Jun-Aug 1986	Yes	Clinical investigation	Moderate
Parakoyi(20)	1990	Nigeria* (Ilorin, Kwara State)	General population (urban/rural)	4,576 children aged 5-9 years	Lameness survey (house-to-house) March 1988	Yes	Clinical investigation	Low
Tekle-Haimanot(21)	1990	Ethiopia* (Meskan & Moreko subdistricts)	General population (rural)	60,820 adults	Lameness survey (house-to-house) 1986-1988	Yes	Clinical investigation	Moderate
Khajuria(22)	1989	India* (Haryana)	General population (rural)	37,851 children aged 1-11 years	Lameness survey (village) 1985	Yes	Clinical investigation	High
Dekker(23)	1988	Ethiopia* (Addis Ababa)	General population	256,092 children aged <20 years	Lameness survey (school) Unknown date	Yes	Clinical investigation	High
Maru(24)	1988	Ethiopia* (Gondar)	General population (urban/rural)	17,941 children aged 5-9 years	Lameness survey (house-to-house) Feb-Jul 1983	Yes	Clinical investigation	Low
Osuntokun(25)	1987	Nigeria* (Igbo-Ora)	General population	18,954	Lameness survey (house-to-house) Unknown date	Yes	Clinical investigation	Moderate
Tidke(26)	1986	India* (Bombay)	General population	15,165 children aged <6 years	Lameness survey (house-to-house)	Yes	Clinical investigation	High

First Author	Year	Country (Region)	Population status	Population base	Study design / Date	Full article	Verification of diagnosis	Risk rating
			(slums)		Unknown date			
Broca(27)	1985	India* (Ajmer City, Rajasthan)	General population	6,000 children aged 5-15 years	Lameness survey (house-to-house) Aug 1981-Mar 1982	Yes	Clinical investigation	Moderate
Basu(28)	1984	India (National)*	General population (urban / rural)	715,039 children aged 5-9 years	Lameness survey (national) 1981-1982	Yes	Clinical investigation	Low
Heymann(29)	1983	Rep. of Cameroon* (Yaounde, Bamenda, Eseka)	General population (urban/rural)	37,130 children aged 5-11 years	Multiple sources (hospital and clinical registers, house-to-house and school lameness survey)	Yes	Clinical investigation	Moderate
Olive(30)	1984	Sudan* (Port Sudan and Juba, Khartoum)	General population (urban / semi-rural)	45,499 children aged 5-13 years	Lameness survey (house-to-house / school) July-Sept 1982	Yes	Clinical investigation	Moderate
Srilatha(31)	1984	South India* (North Arcot District,Tamil Nadu)	General population (rural)	14,643 children aged 5-17 years	Lameness survey (school) June-Dec 1979	Yes	Unknown	High
Hajar(32)	1983	Yemen Arab Republic*	General population (urban / rural)	12,443 children aged 5-13 years	Lameness survey (school and community) Nov 1980 – Jan 1981	Yes	Clinical investigation	Low
Sabin(33)	1983	Brazil (Federal District of Brazil)	General population	20,807 children aged 6-7 and 10-11 years	Lameness survey (school) 1980	Yes	Clinical investigation	Moderate

First Author	Year	Country (Region)	Population status	Population base	Study design / Date	Full article	Verification of diagnosis	Risk rating
Hall(34)	1982	Papua New Guinea* (Gulf Province)	General population	3,368 children (ages unspecified)	Lameness survey (school) 1979	Yes	Unknown	High
Rotti(35)	1982	South India* (Pondicherry)	General population (urban)	6,683 children aged 6-15 years	Lameness survey (house-to-house and school) July 1980-Sept 1981	Yes	Clinical investigation	Moderate
Thuriaux(36)	1982	Niger* (Niamey, Kollo, Tillaberry, Gotheye)	General population (rural/urban)	46,772 children aged 5-14 years	Lower limb motor disorders survey (school) Feb-May 1981	Yes	Clinical investigation	Moderate
Snyder(37)	1981	Bangladesh* (Matlab)	General population (rural)	25,000 children aged 5-14 years	Lameness survey (house-to-house) May-Jun 1979	Yes	Clinical investigation	Moderate
Ulfah(38)	1981	Indonesia* (Yogyakarta)	Philanthropic private agency	94,376 children and adolescents aged <20 years	Lameness survey (families)	Yes	Clinical and laboratory investigation	High
Jhala(39)	1979	India* (Patan Taluka, Gujarat)	General population (rural)	57,435 adults	Lameness survey (house-to-house)	Yes	Clinical investigation	High
Nicholas(40)	1977	Ghana* (Danfa)	General population (rural)	13,232 children aged 0-15 years	Lameness survey (school, village)	Yes	Clinical investigation	High
Hardas(41)	1974	India* (Nagpur)	General population (urban/rural)	36,826 children aged <12 years	Lameness survey (house-to-house)	Yes	Clinical investigation	Moderate
					Low to lower middle income countries – Average prevalence^{+} 425			

First Author	Year	Country (Region)	Population status	Population base	Study design / Date	Full article	Verification of diagnosis	Risk rating
					Upper-middle to high income countries – Average prevalence†	165		
					International – Total average prevalence	**295**		

*Low-to-lower middle income countries.
PPS = Post-polio syndrome.
＋ Based on 18 studies with low to moderate risk of bias.
†Based on 3 studies with low to moderate risk of bias.

PRISMA 2009 Checklist

Section/topic	#	Checklist item	Reported on page #
TITLE			
Title	1	Identify the report as a systematic review, meta-analysis, or both.	1
ABSTRACT			
Structured summary	2	Provide a structured summary including, as applicable: background; objectives; data sources; study eligibility criteria, participants, and interventions; study appraisal and synthesis methods; results; limitations; conclusions and implications of key findings; systematic review registration number.	3
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of what is already known.	4
Objectives	4	Provide an explicit statement of questions being addressed with reference to participants, interventions, comparisons, outcomes, and study design (PICOS).	4
METHODS			
Protocol and registration	5	Indicate if a review protocol exists, if and where it can be accessed (e.g., Web address), and, if available, provide registration information including registration number.	n/a
Eligibility criteria	6	Specify study characteristics (e.g., PICOS, length of follow-up) and report characteristics (e.g., years considered, language, publication status) used as criteria for eligibility, giving rationale.	5
Information sources	7	Describe all information sources (e.g., databases with dates of coverage, contact with study authors to identify additional studies) in the search and date last searched.	5
Search	8	Present full electronic search strategy for at least one database, including any limits used, such that it could be repeated.	5
Study selection	9	State the process for selecting studies (i.e., screening, eligibility, included in systematic review, and, if applicable, included in the meta-analysis).	5
Data collection process	10	Describe method of data extraction from reports (e.g., piloted forms, independently, in duplicate) and any processes for obtaining and confirming data from investigators.	6
Data items	11	List and define all variables for which data were sought (e.g., PICOS, funding sources) and any assumptions and simplifications made.	6
Risk of bias in individual studies	12	Describe methods used for assessing risk of bias of individual studies (including specification of whether this was done at the study or outcome level), and how this information is to be used in any data synthesis.	5
Summary measures	13	State the principal summary measures (e.g., risk ratio, difference in means).	6
Synthesis of results	14	Describe the methods of handling data and combining results of studies, if done, including measures of consistency (e.g., I^2) for each meta-analysis.	6

PRISMA 2009 Checklist

Section/topic	#	Checklist item	Reported on page #
Risk of bias across studies	15	Specify any assessment of risk of bias that may affect the cumulative evidence (e.g., publication bias, selective reporting within studies).	6
Additional analyses	16	Describe methods of additional analyses (e.g., sensitivity or subgroup analyses, meta-regression), if done, indicating which were pre-specified.	n/a
RESULTS			
Study selection	17	Give numbers of studies screened, assessed for eligibility, and included in the review, with reasons for exclusions at each stage, ideally with a flow diagram.	7
Study characteristics	18	For each study, present characteristics for which data were extracted (e.g., study size, PICOS, follow-up period) and provide the citations.	7
Risk of bias within studies	19	Present data on risk of bias of each study and, if available, any outcome level assessment (see item 12).	8
Results of individual studies	20	For all outcomes considered (benefits or harms), present, for each study: (a) simple summary data for each intervention group (b) effect estimates and confidence intervals, ideally with a forest plot.	n/a
Synthesis of results	21	Present results of each meta-analysis done, including confidence intervals and measures of consistency.	8
Risk of bias across studies	22	Present results of any assessment of risk of bias across studies (see Item 15).	9
Additional analysis	23	Give results of additional analyses, if done (e.g., sensitivity or subgroup analyses, meta-regression [see Item 16]).	n/a
DISCUSSION			
Summary of evidence	24	Summarize the main findings including the strength of evidence for each main outcome; consider their relevance to key groups (e.g., healthcare providers, users, and policy makers).	9
Limitations	25	Discuss limitations at study and outcome level (e.g., risk of bias), and at review-level (e.g., incomplete retrieval of identified research, reporting bias).	10
Conclusions	26	Provide a general interpretation of the results in the context of other evidence, and implications for future research.	12
FUNDING			
Funding	27	Describe sources of funding for the systematic review and other support (e.g., supply of data); role of funders for the systematic review.	13

From: Moher D, Liberati A, Tetzlaff J, Altman DG, The PRISMA Group (2009). Preferred Reporting Items for Systematic Reviews and Meta-Analyses: The PRISMA Statement. PLoS Med 6(6): e1000097. doi:10.1371/journal.pmed1000097

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A systematic review of the worldwide prevalence of survivors of poliomyelitis reported in 31 studies.

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Secondary Subject Heading:	Global health
Keywords:	EPIDEMIOLOGY, PUBLIC HEALTH, STATISTICS & RESEARCH METHODS

A systematic review of the worldwide prevalence of survivors of poliomyelitis reported in 31 studies.

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Key words: public health; statistics & research methods; epidemiology.

ABSTRACT

Background Accurate prevalence figures estimating the number of survivors of poliomyelitis (disease causing acute flaccid paralysis), following poliovirus infection are not available. We aim to undertake a systematic review of all literature concerning the prevalence of survivors of poliomyelitis.

Methods Electronic databases were searched from 1900 up to May 2016 for peer-reviewed studies including population-based approach with a defined denominator and some form of diagnostic or clinical verification of polio. Exclusion criteria were any prevalence data were unable to be extracted or calculated and studies reporting on incidence only. The quality of each included study was assessed using an existing tool modified for use in prevalence studies. Average crude prevalence rates were used to calculate worldwide estimates.

Results Thirty-one studies met criteria with 90% of studies conducted in low-to-lower middle-income countries. Significant variability in the prevalence of survivors of poliomyelitis was revealed, in low-to-lower-middle-income (15 per 100,000 in Nigeria to 1,733 in India) and upper-middle to high-income countries (24 (Japan) to 380 per 100,000 (Brazil). The total combined prevalence of survivors of poliomyelitis for those studies at low to moderate risk of bias ranged from 165 (high-income countries) to 425 (low-to-lower middle-income countries) per 100,000 person years. Historical lameness surveys of children predominated, with wide variation in case definition and assessment criteria, and limited relevance to current prevalence given the lack of incidence of poliovirus infection in the ensuing years.

Conclusions These results highlight the need for future epidemiological studies of poliomyelitis to examine nationally representative samples, including all ages and more focus on high-income countries. Such efforts will improve capacity to provide reliable and more robust worldwide prevalence estimates.

Strengths and limitations of this study

- This is the first and largest international systematic review, including 31 studies, of the prevalence of survivors of poliomyelitis.
- The study found significant variability in the reported prevalence of survivors across low to high-income countries.
- There are a lack of studies examining nationally representative samples.
- There are no accurate current data on the prevalence of survivors of poliomyelitis worldwide.

INTRODUCTION

Poliovirus (polio) is a highly infectious, incurable viral disease caused by a wild or live vaccine-derived virus that remains endemic in Afghanistan, Pakistan and Nigeria [1]. Since the creation of the Global Polio Eradication Initiative in 1988, alongside mass vaccination programs aimed at eradicating polio, the number of new cases has been cut by 99% [2] from 350,000 cases to 74 reported cases in 2015 [3]. Polio, a human enterovirus [4], primarily affects children aged <5 years with infection most commonly spread by the faecal-oral route. Up to 75% of poliovirus infections in children are asymptomatic, while approximately 24% of cases may experience a low grade fever and sore throat [5]. Less than 1% of cases experience viral replication in the central nervous system causing temporary or permanent acute flaccid paralysis (AFP) (known as poliomyelitis).[6] While there is wide variability regarding the impact of poliovirus infection, estimates suggest that 12-20 million individuals are living with the consequences of the disease worldwide.[7] Up to 40% of all survivors of acute poliomyelitis will experience post-poliomyelitis syndrome (PPS) [8], being the delayed appearance of new or worsening disabling neuromuscular symptoms 30-40 years after the original poliomyelitis attack.[9] However, recent accurate prevalence rates estimating the number of survivors of poliomyelitis are not available.[10]

Published international prevalence studies are problematic. These studies have (i) tended to focus on the initial disease and needs in the immediate aftermath, (ii) been inconsistent in the definition of "polio survivor," with it often unclear whether this refers all those infected or only those sustaining some form of residual disability, (iii) predominantly focused on health status rather than the everyday effects on people's lives, their needs, and those of their carers, iv) produced inconsistent findings on long-term outcomes, perhaps due to cultural differences, and/or have been (vii) limited to lameness surveys of children in mostly low-to-lower middle-income countries.[11] Hence, regional prevalence estimates are often crude and

fragmentary. This systematic literature review aims to synthesise current knowledge on the prevalence of survivors of poliomyelitis worldwide using all available population-based polio prevalence studies.

METHODS

This review is reported according to the PRISMA Statement.

Search strategy

We searched Medline (1946 to May 2016), CINAHL (1937 to May 2016), Psychology and Behavioral Sciences Collection (1945 to May 2016), ProQuest (1971 to May 2016), Scopus (1970 to May 2016), and Web of Science (1900 to May 2016) databases from inception to May 2016 for relevant studies. A search strategy was developed for Medline using 'post-polio syndrome', 'poliovirus', 'polio', 'postpolio', 'poliomyelitis', 'postpoliomyelitis', 'PPMA', 'PPMD', 'LEOP', or 'late effects of polio' and 'epidemiol', 'rate', 'proportion', or 'prevalence*', and was then repeated for other database searches. The complete search strategy is available online (see supplementary Table S1). Hand searching of included articles was also undertaken.

Selection Criteria.

Inclusion/exclusion criteria

Inclusion criteria were: peer reviewed; written in English; reporting of prevalence of poliomyelitis survivors; use of a population-based, epidemiology approach with a defined denominator; and some form of diagnostic or clinical verification of polio. Only those studies reporting on cases ascertained from a general population sample (i.e., not restricted by gender or ethnicity) were included to enable comparison between populations, and with other

conditions, and to enhance representativeness of the findings. Studies in which any prevalence data were unable to be extracted or calculated, or studies reporting incidence data only were excluded. Duplicate publications reporting on the same research data were also removed.

Quality appraisal

Each study was assessed for methodological quality and risk of bias using a 10-item assessment tool (external (4 items) and internal (6 items) validity) specifically designed for population-based prevalence studies [12]. Further, a summary assessment evaluates the overall risk of study bias based on the 10 items [13]. A summary assessment deeming a study to be at low risk of bias suggests that 'further research is very unlikely to change our confidence in the estimate'. A moderate risk of bias rating suggests that 'further research is likely to have an important impact on our confidence in the estimate and may change the estimate'. The limitations of studies considered to be at high risk of bias suggest that 'further research is very likely to have an important impact on our confidence in the estimate and is likely to change the estimate'. For this review, a study was considered to have a high risk of bias if the target population was not closely representative of the national population, if there was no use of random selection, and if the study had a more than a minimal risk of non-response bias.

Data extraction and synthesis

Two authors (KJ, SB) independently reviewed abstracts for possible inclusion. In cases of non-consensus, an additional independent review was obtained from a third author (VF). Any on-going discrepancies were resolved via discussion. In cases of incomprehensive study methodology, authors were approached to determine a study's potential inclusion. Where possible, copies of full articles were obtained for studies meeting the inclusion criteria. Reviewers extracted standard information per study on study characteristics, target population, research design, and verification of poliovirus infection. Only those studies considered to be at low to moderate risk of bias were included in the calculation of

prevalence estimates. An average prevalence of poliomyelitis is reported for each study as the number of cases per 100,000 people of all ages or a particular age range, depending on the data available. Rates were checked for accuracy where possible, depending on the data provided. Due to a lack of availability of standardized rates, prevalence rates are reported as crude estimate (i.e. unadjusted rates). Studies reporting adjusted values only have not been included the average prevalence calculation. In instances where a range of prevalence rates have been reported in a study and no overall rate reported (e.g. across ethnic groups or different geographical regions or years), we have used the average of this range for the purposes of calculating an overall average prevalence. The research protocol was not subject to ethical approval as no such approval was required according to local regulations.

RESULTS

Included studies

Figure 1 presents an overview of the study selection process. The initial search yielded 1,239 citations. Following scanning of the titles for appropriateness for inclusion, those not meeting criteria and duplicate citations were removed (973). Where available, the abstracts of the remaining 266 potentially relevant titles identified across all sources (EBSCO n = 25; ProQuest n = 17; Scopus n = 88; Web of Science n = 136) were obtained. Following the availability and review of 206 abstracts, 117 full articles were independently evaluated for inclusion by two reviewers (SB, KJ). This process led to the elimination of 86 studies that did not meet the required inclusion criteria. The remaining 31 articles met inclusion criteria and were included in the review.

[INSERT FIGURE 1 ABOUT HERE]

The 31 eligible population-based studies reported data from 14 different countries. Data on polio prevalence in low-to-lower middle-income countries were reported in 28 (90%) studies in 11 countries: India (14 studies); Nigeria (2 studies); Ethiopia (4 studies), and one study in each of the following locations: Indonesia, Ghana, Bangladesh, Niger, Cameroon, Sudan, Yemen, and Papua New Guinea. Population-based data on polio prevalence in upper-middle to high-income countries were available from 3 studies in 3 countries: Japan; Sweden; and Brazil.

Study characteristics

Table 1 provides a summary of the characteristics of those articles included in the review, including details of polio verification, population status, study design, and risk of bias. The included studies reported on polio prevalence data collected between 1974 and 2004. In terms of methodologies implemented across the included studies, poliovirus infection was verified in 28 (90%) cases via the use of clinical investigations (i.e., examination by a physician or similar). Two of these studies also used laboratory investigations (i.e., virological confirmation) to confirm a history of polio. Twenty-nine (94%) of studies presented data collected by lameness surveys. These included surveys of schools (5), villages (1), families (1), house-to-house surveys (16), or a mixture there of (4), and postal questionnaires (1). One lameness survey examined a national population. The remaining two studies (6%) used multiple sources of case ascertainment. Studies most commonly examined urban/rural or semi-rural populations (12), with 8 eight studies limited to rural populations. Only one study reported a specific focus on an urban population. Of the 31 studies included, 26 (84%) presented data based on children and young persons aged <20 years. In terms of risk of bias, the majority of studies (77%) were at moderate (14 studies, 45%) to high (10 studies, 32%) risk of bias (Figure 2). Seven studies (23%) were considered to be at low risk of bias.

[INSERT TABLE 1 ABOUT HERE]

[INSERT FIGURE 2 ABOUT HERE]

Poliomyelitis prevalence

In the general population, crude average prevalence across all included studies ranged from 15 per 100,000 in Nigeria to 1,733 in Ajmer City, India (Figure 3). Among all low-to-lower middle-income countries, crude rates of poliomyelitis prevalence ranged from 15 per 100,000 (Igbo-Ora, Nigeria) to 1,733 per 100,000 (Ajmer City, Rajasthan, India). Among all high-income counties, crude rates of polio prevalence ranged from 24 (PPS) per 100,000 (Japan) to 380 per 100,000 (Brazil). For those studies considered to be at low to moderate risk of bias, prevalence estimates ranged from 92 in Sweden to 730 in Ethiopia. The total combined prevalence of polio for those studies at low to moderate risk of bias ranged from 165 (high-income countries) to 425 (low-to-lower middle-income countries) per 100,000 person years.

[INSERT FIGURE 3 ABOUT HERE]

DISCUSSION

This study reviews all the available data from population-based poliomyelitis prevalence studies. Findings reveal significant discrepancies in average crude unadjusted prevalence rates, both between and within countries. Across all included studies and within low-to-lower middle-income countries, prevalence rates ranged from 15 per 100,000 person-years in Igbo-Ora Nigeria to 1,733 in Ajmer City, India. Within high-income countries, rates ranged from 24 in Japan to 380 in Brazil.

Worldwide variations in prevalence ratings could be attributed to the diversity (and at times a lack of clarity) of applied case definitions and assessment processes to determine a

history of poliomyelitis. For example, while the majority of studies used lameness surveys, some studies were limited to the examination of lower extremity disabilities. Other studies included the examination of upper extremity disabilities in their efforts to identify those affected by poliovirus leading to poliomyelitis. Three studies were limited to the examination of PPS only. Such inconsistencies are of concern given incomplete case ascertainment or disease misclassification can significantly skew the reported prevalence. Even assuming that all cases were ascertained in a given study, data would still omit those survivors of poliomyelitis who are now free from any observable, physical ailments. However, perhaps more problematic are the risks for over-reporting due to the inclusion of cases of non-polio AFP.

Alongside methodological variations and shortcomings discussed above, rather than informing estimates of the prevalence of survivors of poliomyelitis worldwide, limitations in the literature render this review largely of the historical prevalence of residual AFP that may be due to poliomyelitis. AFP is a clinical syndrome with a broad array of possible etiologies (i.e., spinal cord compression, trauma, exposure to chemicals, recent illness) that serves as a proxy for poliomyelitis [14]. Figures from AFP surveillance surveys, an essential strategy of the Global Polio Eradication Initiative [13], suggest that non-polio AFP affects 1-3 cases per 100,000 children aged <15 years per year [15]. Subsequently lameness surveys, most common in this review, risk overstating the prevalence of survivors of polio. Such risks are especially high in areas such as Afghanistan, India and Nigeria who have the highest annualized non-polio AFP rate compared with the number of poliovirus cases [16]. Furthermore, few studies examined the prevalence of survivors of poliomyelitis across all age groups, nor have samples that are representative of the respective national population been studied to inform appropriate gender, age and ethnicity estimates. Findings from lameness

surveys in the current review also have considerable variation in the range of age groups surveyed (i.e., 5-15 years, 0-6 years).

Our findings suggest the average crude worldwide prevalence of 295/100,000 person years. However, many of the studies included in this review were undertaken in geographical areas where rates of non-polio AFP are high, the dated nature of studies (many being published more than 30 years ago) and since aging population, and the 99% reduction in the more recent incidence of poliovirus infection, it must be noted that the actual worldwide prevalence is likely much lower.

This review has provided an overview of studies to date that have endeavored to examine the prevalence of survivors of poliomyelitis. While all efforts were made to identify and access all articles relevant to the review, it is important to acknowledge the likelihood that some studies (i.e., unpublished or inaccessible studies) were not identified by the search strategy and therefore excluded. Well-designed epidemiological studies are clearly required to accurately determine the current prevalence of poliomyelitis survivors, living either with or without AFP.

Future epidemiological polio studies can reduce bias noted in this review by including the use of random or cluster sampling, the examination of populations that are representative of the national population where possible, and the application of clear case definitions and diagnosis. In addition to recommending that future studies to adhere to the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) Statement [17], we offer specific recommendations for the pursuit of future studies examining prevalence of survivors of poliomyelitis in Table 2.

[INSERT TABLE 2 ABOUT HERE]

Table 2. Suggested recommendations for future epidemiological studies of poliomyelitis.

External validity
Examine nationally representative populations to enhance the generalizability of findings
Further prevalence studies are required in high-income countries
Examine all age groups (i.e., adults and children)
Estimate prevalence by age, sex, residency (urban/rural) and ethnic-specific rates
Undertake a census OR use some form of random selection (i.e., cluster sampling)
Extending findings of lameness surveys by also capturing lame-free cases of poliomyelitis (i.e., using multiple sources of case ascertainment including review of medical records)
Use an established risk of bias tool specifically designed for use in population-based studies
Internal validity
Standard case definition and clinical evaluation
Describe any efforts to address potential sources of bias
Appropriate numerator (s) and denominator (s)

Conclusions

In conclusion, this review reported prevalence of poliomyelitis survivors worldwide from all identified studies. The majority of research to date has been limited to the examination of children and adolescents in low to lower middle-income countries (predominantly India) who reside in geographical regions that are not representative of the national population (in terms of age, sex, ethnic distributions, for example) and face high rates of non-polio AFP. Further research of the prevalence of survivors of poliomyelitisis required using a population-based

approach, examining nationally representative samples of all ages, particularly in high income countries including those declared to be polio-free. Such efforts will reduce risks for sampling and measurement bias and improve capacity to provide reliable and more robust worldwide prevalence estimates.

Competing Interests None declared.

Disclosure of conflict of interest There are no conflicts of interest.

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Legends

Figure 1. Flow diagram of included/excluded studies.

Figure 2. Risk of bias summary of included population-based studies in reverse chronological order.

Figure 3. Poliomyelitis prevalence by country income level.

Contributorship statement

GJ conceived on the study. SB conducted searches and extracted the data. KJ and SB compiled and analyzed data. VF, AT and GJ advised throughout the study. KJ prepared the initial draft of the manuscript. All authors provided conceptual input and critical review of drafts.

Data sharing statement

No additional data available.

Table 1. Details of included population-based studies in reverse chronological order.

First Author	Year	Country (Region)	Population status	Population base	Study design / Date	Full article	Verification of diagnosis	Risk rating
Takemura[18]	2004	Japan (Kitakyushu)	Registry of 13,000 physically disabled persons	342	Lameness survey (postal questionnaire)	Yes	Clinical investigation	Moderate
Tessema[19]	2001	Ethiopia* (Gondar Zuria district)	General population (urban/rural)	12,000 children aged 1-15 years	Lameness survey (house-to-house) Jul-Aug 1993	Yes	Clinical investigation	Low
Anand[20]	1998	India* (Ballabgarh, Haryana)	General population (rural)	28,464 children aged <15 years	Lameness survey (house-to-house) Dec 1996	Yes	Clinical and laboratory investigation	High
Srinivasa[21]	1997	India* (Pondicherry)	General population (urban/rural)	Approx. 11,000 children aged <60 months	Lameness survey (house-to-house) Jan-Feb of each year between 1989-91	Yes	Clinical investigation	Moderate
Ahlstrom[22]	1993	Sweden (Orebro)	General population (urban/rural)	269,341	Multiple sources (hospital, outpatient, institutional, insurance, medical records) 01 Jan 1988	Yes	Search of clinical records	Low
Soudarssane[23]	1993	India* (Pondicherry)	General population	47,960 children aged 0-6 years	Lameness survey (house-to-house) Apr-Jul 1989	Yes	Clinical investigation	Low
Kumar[24]	1991	India* (Ambala, Haryana State)	General population	15,761 children aged <15 years	Lameness survey (house-to-house) Jan 1989	Yes	Clinical investigation	High
Balraj[25]	1990	India* (Northern	General population	42,045 children aged <5 years	Lameness survey (house-to-house)	Yes	Clinical investigation	Moderate

First Author	Year	Country (Region)	Population status	Population base	Study design / Date	Full article	Verification of diagnosis	Risk rating
		Arcot District, Tamil Nadu State)	(rural)		Feb-Oct 1988			
Mehra[26]	1990	India* (New Delhi)	General population (urban/rural)	7,318 children aged 5-15 years	Lameness survey (house-to-house) Jun-Aug 1986	Yes	Clinical investigation	Moderate
Parakoyi[27]	1990	Nigeria* (Ilorin, Kwara State)	General population (urban/rural)	4,576 children aged 5-9 years	Lameness survey (house-to-house) March 1988	Yes	Clinical investigation	Low
Tekle-Haimanot[28]	1990	Ethiopia* (Meskan & Moreko subdistricts)	General population (rural)	60,820 adults	Lameness survey (house-to-house) 1986-1988	Yes	Clinical investigation	Moderate
Khajuria[29]	1989	India* (Haryana)	General population (rural)	37,851 children aged 1-11 years	Lameness survey (village) 1985	Yes	Clinical investigation	High
Dekker[30]	1988	Ethiopia* (Addis Ababa)	General population	256,092 children aged <20 years	Lameness survey (school) Unknown date	Yes	Clinical investigation	High
Maru[31]	1988	Ethiopia* (Gondar)	General population (urban/rural)	17,941 children aged 5-9 years	Lameness survey (house-to-house) Feb-Jul 1983	Yes	Clinical investigation	Low
Osuntokun[32]	1987	Nigeria* (Igbo-Ora)	General population	18,954	Lameness survey (house-to-house) Unknown date	Yes	Clinical investigation	Moderate
Tidke[33]	1986	India* (Bombay)	General population	15,165 children aged <6 years	Lameness survey (house-to-house)	Yes	Clinical investigation	High

First Author	Year	Country (Region)	Population status	Population base	Study design / Date	Full article	Verification of diagnosis	Risk rating
			(slums)		Unknown date			
Broca[34]	1985	India* (Ajmer City, Rajasthan)	General population	6,000 children aged 5-15 years	Lameness survey (house-to-house) Aug 1981-Mar 1982	Yes	Clinical investigation	Moderate
Basu[35]	1984	India (National)*	General population (urban / rural)	715,039 children aged 5-9 years	Lameness survey (national) 1981-1982	Yes	Clinical investigation	Low
Heymann[36]	1983	Rep. of Cameroon* (Yaounde, Bamenda, Eseka)	General population (urban/rural)	37,130 children aged 5-11 years	Multiple sources (hospital and clinical registers, house-to-house and school lameness survey)	Yes	Clinical investigation	Moderate
Olive[37]	1984	Sudan* (Port Sudan and Juba, Khartoum)	General population (urban / semi-rural)	45,499 children aged 5-13 years	Lameness survey (house-to-house / school) July-Sept 1982	Yes	Clinical investigation	Moderate
Srilatha[38]	1984	South India* (North Arcot District,Tamil Nadu)	General population (rural)	14,643 children aged 5-17 years	Lameness survey (school) June-Dec 1979	Yes	Unknown	High
Hajar[39]	1983	Yemen Arab Republic*	General population (urban / rural)	12,443 children aged 5-13 years	Lameness survey (school and community) Nov 1980 – Jan 1981	Yes	Clinical investigation	Low
Sabin[40]	1983	Brazil (Federal District of Brazil)	General population	20,807 children aged 6-7 and 10-11 years	Lameness survey (school) 1980	Yes	Clinical investigation	Moderate

First Author	Year	Country (Region)	Population status	Population base	Study design / Date	Full article	Verification of diagnosis	Risk rating
Hall[41]	1982	Papua New Guinea* (Gulf Province)	General population	3,368 children (ages unspecified)	Lameness survey (school) 1979	Yes	Unknown	High
Rotti[42]	1982	South India* (Pondicherry)	General population (urban)	6,683 children aged 6-15 years	Lameness survey (house-to-house and school) July 1980-Sept 1981	Yes	Clinical investigation	Moderate
Thuriaux[43]	1982	Niger* (Niamey, Kollo, Tillaberry, Gotheye)	General population (rural/urban)	46,772 children aged 5-14 years	Lower limb motor disorders survey (school) Feb-May 1981	Yes	Clinical investigation	Moderate
Snyder[44]	1981	Bangladesh* (Matlab)	General population (rural)	25,000 children aged 5-14 years	Lameness survey (house-to-house) May-Jun 1979	Yes	Clinical investigation	Moderate
Ulfah[45]	1981	Indonesia* (Yogyakarta)	Philanthropic private agency	94,376 children and adolescents aged <20 years	Lameness survey (families)	Yes	Clinical and laboratory investigation	High
Jhala[46]	1979	India* (Patan Taluka, Gujarat)	General population (rural)	57,435 adults	Lameness survey (house-to-house)	Yes	Clinical investigation	High
Nicholas[47]	1977	Ghana* (Danfa)	General population (rural)	13,232 children aged 0-15 years	Lameness survey (school, village)	Yes	Clinical investigation	High
Hardas[48]	1974	India* (Nagpur)	General population (urban/rural)	36,826 children aged <12 years	Lameness survey (house-to-house)	Yes	Clinical investigation	Moderate
					Low to lower middle income countries – Average prevalence^{+} 425			

First Author	Year	Country (Region)	Population status	Population base	Study design / Date	Full article	Verification of diagnosis	Risk rating
					Upper-middle to high income countries – Average prevalence†		165	
					International – Total average prevalence		**295**	

*Low to lower-middle income countries.
PPS = Post-polio syndrome.
+ Based on 18 studies with low to moderate risk of bias.
†Based on 3 studies with low to moderate risk of bias.

References

1. Toole MJ. So close: remaining challenges to eradicating polio. *BMC Med* 2016;**14**(43) doi: http://dx.doi.org/10.1186/s12916-016-0594-6.

2. Global Polio Eradication Initiative. Global polio eradication initiative annual report 2007: Impact of the intensified eradication effort. Switzerland: World Health Organisation, 2008.

3. World Health Organisation. Poliomyelitis Fact Sheet Updated April 2016, 2016.

4. Dowdle WR, Birmingham ME. The biologic principles of poliovirus eradication. *The Journal of Infectious Diseases* 1997;**175**((Suppl 1)):S286-92

5. Centers for Disease Control and Prevention. Poliomyelitis In: .J H, Kroger A, Wolfe C, eds. Epidemiology and Prevention of Vaccine-Preventable Diseases (The Pink Book). 13 ed. Washington DC: Public Health Foundation, 2015.

6. Shibuya K, Murray CJL. Poliomyelitis. In: C.L. M, Lopez AD, Mathers C, et al., eds. The global epidemiology of infectious diseases. Geneva: World Health Organisation, 2004:111-49.

7. Petrie KJ, Weinman J. Why illness perceptions matter. *Clin Med* 2006;**6**(6):536-39

8. Lin KH, Lim YW. Post-poliomyelitis syndrome: case report and review of the literature. *Annals-academy of Medicine Singapore* 2005;**34**(7):447

9. Matz K, Teuschl Y, Firlinger B, et al. Multidomain lifestyle interventions for the prevention of cognitive decline after ischemic stroke: Randomized trial. *Stroke* 2015;**46**(10):2874-80 doi: 10.1161/STROKEAHA.115.009992.

10. Mulhern S, McMillan TM. Knowledge and expectation of post-concussion symptoms in the general population. *Journal of Psychosomatic Research* 2006;**61**:439-45

11. Burholt V, Nash P. Short Form 36 (SF-36) Health Survey Questionnaire: normative data for Wales. *J Public Health Dent* 2011;**33**(4):587-603 doi: http://dx.doi.org/1093/pubmed/fdr006.

12. Hoy D, Brooks P, Woolf A, et al. Assessing risk of bias in prevalence studies: Modification of an existing tool and evidence of interrater agreement. *J Clin Epidemiol* 2012;**65**:934-39

13. Nathanson N, Kew OM. From emergence to eradication: The epidemiology of poliomyelitis deconstructed. *American Journal of Epidemiology* 2010;**172**(11):1213-29 doi: 10.1093/aje/kwq320.

14. Growdon JH, Fink JS. Paralysis and movement disorder. In: Isselbacher KJ, Braunwald E, Wilson JD, eds. Harrison's principles of internal medicine. New York: McGraw-Hill Book Company, 1994:115-25.

15. Snider CJ, Diop OM, Burns CC, et al. Surveillance Systems to Track Progress Toward Polio Eradication — Worldwide, 2014–2015. MMWR Morb Mortal Wkly Rep, 2016:346-51.

16. Mateen FJ, Black RE. Expansion of acute flaccid paralysis surveillance: beyond poliomyelitis. *Trop Med Int Health* 2013;**18**(11):1421-22 doi: http://dx.doi.org/10.1111/tmi.12181.

17. von Elm E, Altman DG, Egger M, et al. The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) Statement: Guidelines for Reporting Observational Studies. *Ann Intern Med* 2007;**147**(8):573-77 doi: http://dx.doi.org/10.7326/0003-4819-147-8-200710160-00010-w1.

18. Takemura J, Saeki S, Hachisuka K, et al. Prevalence of post-polio syndrome based on a cross-sectional survey in Kitakyushu, Japan. *J Rehabil Med* 2004;**36**(1):1-3

19. Tessema T, Hailu A. Epidemiology of poliomyelitis in northwestern Ethiopia. *East Afr Med J* 2001;**78**(8):430-2

20. Anand K, Kant S, Kumar G, et al. Thirty year trend (1967-1996) in prevalence of poliomyelitis and vaccine coverage in Ballabgarh, Haryana, India. *J Epidemiol Community Health* 1998;**52**(12):823-25

21. Srinivasa DK, Sahai A, Rotti SB, et al. Poliomyelitis trends in Pondicherry, South India, 1989-91. *J Epidemiol Community Health* 1997;**51**(4):443-8

22. Ahlström G, Gunnarsson LG, Leissner P, et al. Epidemiology of Neuromuscular Diseases, Including the Postpolio Sequelae, in a Swedish County. *Neuroepidemiology* 1993;**12**(5):262-69

23. Soudarssanane MB, Rotti SB, Srinivasa DK, et al. Paralytic poliomyelitis in children under 6 years in Pondicherry: a community survey. *J Epidemiol Community Health* 1993;**47**(3):210-14 doi: 10.1136/jech.47.3.210.

24. Kumar R, Kumar V. Poliomyelitis control by annual immunization campaigns with oral polio-virus vaccine in a rural area of India. *Trop Geogr Med* 1991;**43**(1-2):215-9

25. Balraj V, John JT, Thomas M, et al. Efficacy of Oral Poliovirus Vaccine in Rural Communities of North Arcot District, India. *Int J Epidemiol* 1990;**19**(3):711-14 doi: 10.1093/ije/19.3.711.

26. Mehra M, Bansal Y. Prevalence of paralytic poliomyelitis in a rural and urban community of Delhi. *Indian Pediatr* 1990;**27**(9):915-7

27. Parakoyi B, Babaniyi OA. Prevalence of paralytic poliomyelitis in children of Kwara State, Nigeria: report of a house-to-house survey. *East Afr Med J* 1990;**67**(8):545-9

28. Tekle-Haimanot R, Abebe M, Gebre-Mariam A, et al. Community-based study of neurological disorders in rural central Ethiopia. *Neuroepidemiology* 1990;**9**(5):263-77

29. Khajuria R, Datta N, Kumar R, et al. Impact of annual immunisation programme with oral polio vaccine on the prevalence of paralytic poliomyelitis. *The Indian Journal of Pediatrics* 1989;**56**(3):343-7

30. Dekker PA, Green-Abate C. Prevalence of residual paralysis due to poliomyelitis in schoolchildren in Addis Ababa. *Ethiop Med J* 1988;**26**(3):133-8

31. Maru M, Getahun A, Hoshna S. Prevalence of paralytic poliomyelitis in rural and urban populations in Ethiopia: report of a house-to-house survey. *Am J Trop Med Hyg* 1988;**38**(3):633-5

32. Osuntokun BO, Adeuja AOG, Schoenberg BS, et al. Neurological disorders in Nigerian Africians: A community-based study. *Acta Neurol (Napoli)* 1987;**75**(1):13-21

33. Tidke RW, Joshi U, Patel RB. Paralytic poliomyelitis in slums of Bombay. *The Indian Journal of Pediatrics* 1986;**53**(1):109-13 doi: 10.1007/bf02787081.

34. Broca JS, Chaturvedi SK, Mathur GM. Prevalence of residual polio paralysis in children of 5-15 years age group in Ajmer City. *Indian J Public Health* 1985;**29**(3):193-200

35. Basu Rf, Sokhey J. Prevalence of poliomyelitis in India. *The Indian Journal of Pediatrics* 1984;**51**(5):515-19 doi: 10.1007/bf02776613.

36. Heymann DL, Floyd VD, Lichnevski M, et al. Estimation of incidence of poliomyelitis by three survey methods in different regions of the United Republic of Cameroon. *Bull World Health Organ* 1983;**61**(3):501-07

37. Olive JM, Gadir A, Abbas M. Prevalence of residual paralysis from paralytic poliomyelitis in some urban and semi-rural areas of the Sudan, November 1982. *J Trop Pediatr* 1984;**30**(6):329-33

38. Srilatha V, Mukarji D, John TJ. The Prevalence of Poliomyelitis in Rural School Children in South India. *J Trop Pediatr* 1984;**30**(2):68-69 doi: 10.1093/tropej/30.2.68.

39. Hajar M, Zeid A, Saif M, et al. Prevalence, incidence, and epidemiological features of poliomyelitis in the Yemen Arab Republic. *Bull World Health Organ* 1983;**61**(2):353

40. Sabin AB, Silva E. Residual paralytic poliomyelitis in a tropical region of Brazil, 1969–1977: prevalence surveys in different age groups as indicators of changing incidence. *Am J Epidemiol* 1983;**117**(2):193-200

41. Hall AJ. A survey of lameness in school children in Gulf Province. *P N G Med J* 1982;**25**(1):26-8

42. Rotti SB, Satpathy SK, Mehta SP. Prevalence of paralytic poliomyelitis in Pondicherry, South India. *J Epidemiol Community Health* 1982;**36**(4):279-81 doi: 10.1136/jech.36.4.279.

43. Thuriaux MC. A prevalence survey of lower limb motor disorders in school-age children in Niger and an estimation of poliomyelitis incidence. *Trop Geogr Med* 1982;**34**(2):163-8

44. Snyder JD, Black RE, Baqui AH, et al. Prevalence of residual paralysis from paralytic poliomyelitis in a rural population of Bangladesh. *Am J Trop Med Hyg* 1981;**30**(2):426-30

45. Ulfah NM, Parastho S, Sadjimin T, et al. Polio and Lameness in Yogyakarta, Indonesia. *Int J Epidemiol* 1981;**10**(2):171-75 doi: 10.1093/ije/10.2.171.

46. Jhala CI, Goel RK, Dave SK. Epidemiology of poliomyelitis in rural area of Gujarat -- a report of house to house survey in Patan Taluka. *Indian J Med Sci* 1979;**33**(6):143-9

47. Nicholas DD, Kratzer JH, Ofosu-Amaah S, et al. Outside Europe. Is poliomyelitis a serious problem in developing countries?--the Danfa experience. *BMJ* 1977;**1**(6067):1009-12 doi: 10.1136/bmj.1.6067.1009.

48. Hardas U, Waikar A. Pilot survey of disabled children in and around Nagpur. *The Indian Journal of Pediatrics* 1974;**41**(8):267-71 doi: 10.1007/bf02829306.

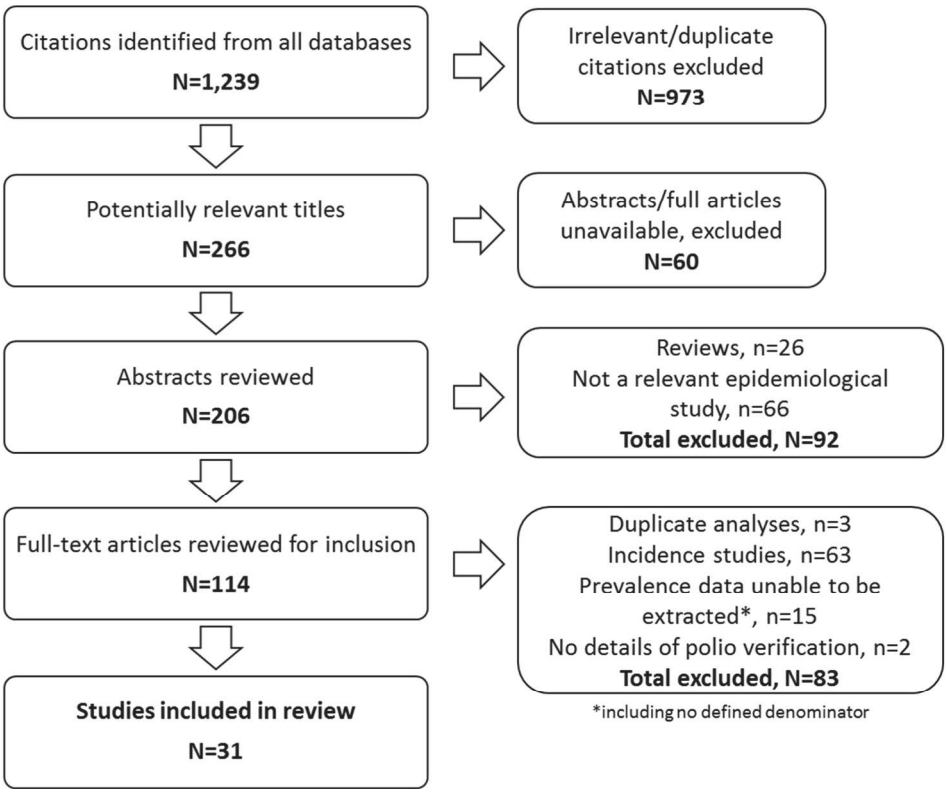

Figure 1. Flow diagram of included/excluded studies.

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	Target population close representation of national	Sampling frame true representation of target population	Random selection used	Minimal risk of non-response bias	Data collected from subjects (not a proxy)	Acceptable case definition	Reliable and validity measurement of parameter of	Consistent mode of data collection	Appropriate prevalence period	Appropriate numerators and denominators	Overall risk
Takemura 2004	✗	✓	✓	✗	✓	✓	✗	✓	✓	✓	Moderate
Tessema 2001	✗	✓	✓	✗	✓	✓	✓	✓	✓	✓	Low
Anand 1998	✗	✗	✗	✗	✓	✓	✓	✓	✓	✓	High
Srinivasa 1997	✗	✓	✗	✗	✓	✓	✓	✓	✓	✓	Moderate
Ahlstrom 1993	✓	✓	✓	✗	✗	✓	✓	✓	✓	✓	Low
Soudarssane 1993	✗	✓	✓	✗	✓	✓	✓	✓	✓	✓	Low
Kumar 1991	✗	✗	✗	✗	✗	✗	✓	✓	✓	✓	High
Balraj 1990	✗	✓	✓	✗	✓	✓	✗	✓	✓	✓	Moderate
Mehra 1990	✗	✓	✗	✗	✓	✓	✓	✓	✓	✓	Moderate
Parakoyi 1990	✗	✓	✓	✗	✓	✓	✓	✓	✓	✓	Low
Tekle-Haimanot 1990	✗	✓	✓	✓	✓	✗	✗	✓	✓	✓	Moderate
Khajuria 1989	✗	✗	✗	✗	✗	✓	✗	✗	✓	✓	High
Maru 1988	✗	✓	✓	✗	✓	✓	✓	✓	✓	✓	Low
Osuntokun 1987	✗	✓	✓	✗	✓	✗	✗	✓	✓	✓	Moderate
Tidke 1986	✗	✗	✗	✗	✓	✓	✓	✓	✓	✓	High
Broca 1985	✗	✓	✓	✗	✓	✓	✗	✓	✓	✓	Moderate
Basu 1984	✓	✓	✓	✗	✓	✗	✓	✓	✓	✓	Low
Olive 1984	✗	✓	✓	✗	✓	✗	✓	✓	✓	✓	Moderate
Srilatha 1984	✗	✓	✗	✗	✓	✗	✓	✓	✓	✓	High
Hajar 1983	✓	✓	✓	✗	✓	✓	✓	✓	✓	✓	Low
Heymann 1983	✗	✓	✓	✗	✓	✓	✓	✗	✓	✓	Moderate
Sabin 1983	✗	✓	✗	✗	✓	✓	✓	✓	✓	✓	Moderate
Dekker 1982	✗	✗	✗	✗	✓	✗	✗	✓	✓	✓	High
Hall 1982	✗	✓	✗	✗	✗	✓	✗	✗	✓	✓	High
Rotti 1982	✗	✓	✗	✗	✓	✓	✓	✓	✓	✓	Moderate
Thuriaux 1982	✗	✓	✓	✗	✓	✓	✗	✓	✓	✓	Moderate
Snyder 1981	✗	✓	✗	✗	✓	✓	✓	✓	✓	✓	Moderate
Ulfah 1981	✗	✗	✗	✗	✓	✓	✓	✗	✓	✓	High
Nicholas 1977	✗	✗	✗	✗	✗	✓	✓	✗	✓	✓	High
Hardas 1974	✗	✓	✓	✗	✓	✗	✓	✓	✓	✓	Moderate
Jhala 1973	✗	✗	✗	✗	✓	✓	✓	✓	✓	✓	High

Figure 2. Risk of bias summary of included population-based studies in reverse chronological order.

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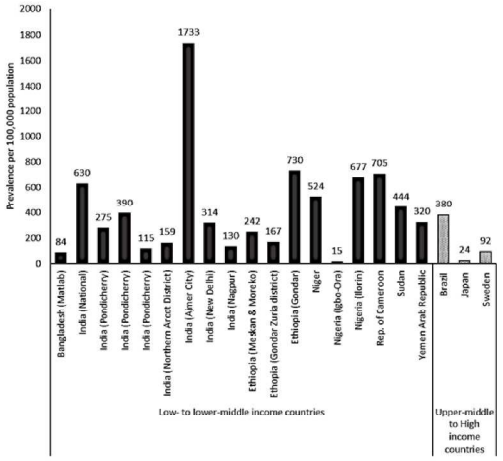

Figure 3. Poliomyelitis prevalence by country income level.

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Supplementary Table 1. Full search criteria for studies assessing prevalence of survivors of polio.

Database (number of hits)	Search Terms
	1.post-polio syndrome
	2.poliovirus
	3.polio
	4.postpolio
PROQUEST (17)	5.poliomyelitis
SCOPUS (88)	6.postpoliomyelitis
WEB OF SCIENCE (136)	7.PPMA
EBSCO (Medline, CINAHL, and Psychology & Behavioral Sciences) (25)	8.PPMD
PROQUEST (17)	9.LEOP
	10.late effects of polio
	11.1 or 2 or 3 or 4 or 5 or 6 or 7 or 8 or 9 or 10
	12.epidemol
	13.rate
	14.proportion
	15.prevalence*
	16.11 and 12 or 13 or 14 or 15

The original search date across all databases was 15th of May 2016.

PRISMA 2009 Checklist

Section/topic	#	Checklist item	Reported on page #
TITLE			
Title	1	Identify the report as a systematic review, meta-analysis, or both.	1
ABSTRACT			
Structured summary	2	Provide a structured summary including, as applicable: background; objectives; data sources; study eligibility criteria, participants, and interventions; study appraisal and synthesis methods; results; limitations; conclusions and implications of key findings; systematic review registration number.	3
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of what is already known.	4
Objectives	4	Provide an explicit statement of questions being addressed with reference to participants, interventions, comparisons, outcomes, and study design (PICOS).	4
METHODS			
Protocol and registration	5	Indicate if a review protocol exists, if and where it can be accessed (e.g., Web address), and, if available, provide registration information including registration number.	n/a
Eligibility criteria	6	Specify study characteristics (e.g., PICOS, length of follow-up) and report characteristics (e.g., years considered, language, publication status) used as criteria for eligibility, giving rationale.	5
Information sources	7	Describe all information sources (e.g., databases with dates of coverage, contact with study authors to identify additional studies) in the search and date last searched.	5
Search	8	Present full electronic search strategy for at least one database, including any limits used, such that it could be repeated.	5
Study selection	9	State the process for selecting studies (i.e., screening, eligibility, included in systematic review, and, if applicable, included in the meta-analysis).	5
Data collection process	10	Describe method of data extraction from reports (e.g., piloted forms, independently, in duplicate) and any processes for obtaining and confirming data from investigators.	6
Data items	11	List and define all variables for which data were sought (e.g., PICOS, funding sources) and any assumptions and simplifications made.	6
Risk of bias in individual studies	12	Describe methods used for assessing risk of bias of individual studies (including specification of whether this was done at the study or outcome level), and how this information is to be used in any data synthesis.	5
Summary measures	13	State the principal summary measures (e.g., risk ratio, difference in means).	6
Synthesis of results	14	Describe the methods of handling data and combining results of studies, if done, including measures of consistency (e.g., I^2) for each meta-analysis.	6

PRISMA 2009 Checklist

Section/topic	#	Checklist item	Reported on page #
Risk of bias across studies	15	Specify any assessment of risk of bias that may affect the cumulative evidence (e.g., publication bias, selective reporting within studies).	6
Additional analyses	16	Describe methods of additional analyses (e.g., sensitivity or subgroup analyses, meta-regression), if done, indicating which were pre-specified.	n/a
RESULTS			
Study selection	17	Give numbers of studies screened, assessed for eligibility, and included in the review, with reasons for exclusions at each stage, ideally with a flow diagram.	7
Study characteristics	18	For each study, present characteristics for which data were extracted (e.g., study size, PICOS, follow-up period) and provide the citations.	7
Risk of bias within studies	19	Present data on risk of bias of each study and, if available, any outcome level assessment (see item 12).	8
Results of individual studies	20	For all outcomes considered (benefits or harms), present, for each study: (a) simple summary data for each intervention group (b) effect estimates and confidence intervals, ideally with a forest plot.	n/a
Synthesis of results	21	Present results of each meta-analysis done, including confidence intervals and measures of consistency.	8
Risk of bias across studies	22	Present results of any assessment of risk of bias across studies (see Item 15).	9
Additional analysis	23	Give results of additional analyses, if done (e.g., sensitivity or subgroup analyses, meta-regression [see Item 16]).	n/a
DISCUSSION			
Summary of evidence	24	Summarize the main findings including the strength of evidence for each main outcome; consider their relevance to key groups (e.g., healthcare providers, users, and policy makers).	9
Limitations	25	Discuss limitations at study and outcome level (e.g., risk of bias), and at review-level (e.g., incomplete retrieval of identified research, reporting bias).	10
Conclusions	26	Provide a general interpretation of the results in the context of other evidence, and implications for future research.	12
FUNDING			
Funding	27	Describe sources of funding for the systematic review and other support (e.g., supply of data); role of funders for the systematic review.	13

From: Moher D, Liberati A, Tetzlaff J, Altman DG, The PRISMA Group (2009). Preferred Reporting Items for Systematic Reviews and Meta-Analyses: The PRISMA Statement. PLoS Med 6(6): e1000097. doi:10.1371/journal.pmed1000097

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