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Cost-effectiveness of interventions to prevent road traffic injuries in low- and middle-income countries: A literature review

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ABSTRACT

Objective: To identify, critically appraise, summarise and synthesise evidence from Cost-Effectiveness Analyses (CEA) of interventions aimed at preventing Road Traffic Injuries (RTIs) in Low- and Middle-Income Countries (LMICs) by age group and road users targeted.

Methods: A search strategy was applied to twelve electronic databases for studies published between May 2002 and August 2015 that met pre-specified inclusion criteria. Additional studies were identified by contacting authors and searching bibliographies. Included studies were critically appraised against published criteria and a narrative synthesis was conducted including a use of the strength of evidence criteria.

Results: Five studies were included in the final review that reported nine interventions. Only two out of nine interventions (drink-drive legislation with enforcement via breath testing campaign, and combined interventions for reducing RTIs) showed moderate evidence of being cost-

effective while the evidence of cost-effectiveness of other interventions was weak. Only two interventions (bicycle and motorcycle helmet use legislation and enforcement) were explicitly targeted to children, young people and vulnerable road users such as pedestrians and cyclists. The cost-effectiveness of interventions to prevent RTIs in LMICs ranged from US\$4.14 per DALYs averted for building speed bumps at the most dangerous junctions that caused 10 percent of junction deaths in the area studied, to US\$3,403 per DALYs averted for legislation and enforcement of helmet use by motorcyclists in the WHO sub-Saharan Africa region.

Conclusions: Evidence of cost-effectiveness of interventions to prevent RTIs in LMICs is limited, particularly for children, young people and vulnerable road users. Evaluation of the effectiveness and cost-effectiveness of a larger number of possible road safety interventions in a variety of LMIC settings are warranted to generate the evidence base for effective traffic injury prevention programmes.

Keywords

low- and middle-income countries, cost-effectiveness analysis, interventions, road traffic injuries, systematic review, vulnerable road users

INTRODUCTION

Around 1.2 million road traffic deaths and between 20 and 50 million non-fatal Road Traffic Injuries (RTIs) occur each year globally (WHO 2013a; WHO 2015), making them the ninth leading cause of death (WHO 2014) with an impact comparable to that caused by malaria (WHO 2013a). The World Health Organization estimates that RTIs will be the seventh leading global cause of death by 2030 (WHO 2013b). Although all age groups are at risk, young people are particularly affected (WHO 2015). Half of all global road traffic deaths occur among the vulnerable road users (pedestrians, bicyclists, motorcyclists and their passengers). Although Low and Middle Income Countries (LMICs) are home to less than 40% of the world's vehicles (Scuffham 2008), more than 90% of global road traffic deaths occur in these countries (WHO 2015; WHO 2013a).

There are economic costs associated with RTIs at individual and national levels. Costs are associated with provision of care and rehabilitation, and with the loss of an economic workforce through disability or premature death (Ameratunga 2006; Mohan 2003; Nguyen et al. 2013). RTIs alone cost governments approximately 3% to 5% of Gross Domestic Product (GDP) each year (WHO 2015). Therefore, given such high costs associated with RTIs, an important step in implementing RTI prevention programmes is to develop and evaluate economically the interventions that work best regarding both saving lives and reducing costs to society.

Given the burden of RTIs in LMICs (WHO 2015), the development of effective interventions (Brown 2007; de Andrade et al. 2008; Law et al. 2005; Soori et al. 2009; WHO 2015), the challenge of translating such interventions from high-income settings to LMICs (Esperato et al.

2012; Stevenson et al. 2008), and the relative paucity of evidence of cost-effectiveness studies in LMICs (Peden et al 2004; Waters et al. 2004), there is a need to better understand the current evidence arising from Cost-Effectiveness Analysis (CEA) of interventions to prevent RTIs in the context of LMICs.

Wesson et al. (2014) reported a systematic review of studies describing the economic burden of injury and trauma in LMICs. The review identified 68 studies meeting the inclusion criteria, of which 31 considered the economic burden of RTIs, although only six of these were full economic studies. The cost-effectiveness of these interventions ranged from US\$10.90 per DALY averted for speed bump installation to US\$17,000 per DALY averted for drunk driving and breath testing campaigns in South Africa. The review concluded that despite the limited evidence available there was the potential for RTI prevention interventions to be cost-effective although there was a clear need to better understand the costs of injuries and injury prevention in these settings.

Therefore, the aim of this review was to build upon the evidence identified by Wesson et al. (2014) and to specifically focus on the most vulnerable road users (children and those who are pedestrians, cyclists and motorcycle drivers and passengers), and to present the findings using strength of evidence criteria.

METHODS

Inclusion Criteria

Inclusion criteria were specified prior to the search for evidence: Type of participants were people of any age, living in a country classified by the World Bank (2015) as low or middle income; Type of interventions were any designed to prevent RTIs; Type of outcome measures were Cost-Effectiveness Analysis (CEA), Incremental Cost-Effectiveness Ratios (ICERs) and incremental cost per DALYs averted. The types of studies included randomised and non-randomised controlled trials, controlled before-after studies and non-intervention studies such as interrupted time-series or other observational studies such as cohort, case-control and cross-sectional studies or modelling studies that report or reference evidence of effectiveness elsewhere and describe evidence of CEA, return on investment or value for health benefits.

Search Strategy

A search strategy was designed in MEDLINE (via OVID) to include free text words and thesaurus headings and adapted for use with other bibliographic databases using appropriate vocabulary and syntax (Table A1). A search filter to identify LMICs produced by Norwegian Satellite of the Cochrane Effective Practice and Organisation of Care Groups (Cochrane 2015) was adapted to identify studies relevant to LMICs. The UK National Health Service Economic Evaluation Database (NHS EED) filter was used to identify economic evaluation articles (Nixon et al. 2000).

The search strategy was applied to twelve electronic databases; MEDLINE, EMBASE, CINAHL Plus, PsycINFO, the Cochrane Central Register of Controlled Trials, the Cochrane Injuries Group's Specialised Register, EconLit, Index Medicus for the South-East Asia Region, World Health Organisation Library Information System, OpenGrey, African Index Medicus, and Index

Medicus for the Eastern Mediterranean Region. An English language restriction was applied. Studies were limited to those published since a comprehensive review of economic evaluations of RTIs published by Waters et al. (2004). Search dates were therefore between May 2002 and August 2015.

The reference lists of all included and relevant studies were checked, and a further search in MEDLINE was conducted for additional papers by the first authors of included studies. We attempted to contact via email all authors of included studies to obtain information on any ongoing, published or unpublished studies related to this topic. The first 100 papers identified by a search of Google Scholar on 8th August 2015 using the terms '*health economics and RTIs*' were also screened for studies meeting inclusion criteria.

Data Extraction and Analysis

Included studies were critically appraised prior to data extraction and synthesis using the 19-point Consensus on Health Economic Criteria (CHEC)-list (Evers et al. 2005). Each included study was then awarded an overall study quality rating ('++', '+' or '-') for internal validity and reporting standards. Data extraction was conducted by AB and queries resolved through discussion with JM. All costs were converted to 2013 US dollars (US\$) by applying the GDP deflator index and purchasing power parities conversion rate to compare the CEA of the included studies using CCEMG-Evidence for Policy and Practice Information and Coordinating Centre (EPPI-Centre) Cost Converter (V1.4) (Shemilt et al. 2010).

Studies were summarised and synthesised using tabulation and narrative synthesis including evidence statements. A meta-analysis was not feasible because of the heterogeneity of studies and the relative brevity of economic evaluation reporting (CRD 2008). The terms used to state the overall strength of the evidence regarding quality, quantity and consistency were adapted from UK National Institute for Health and Care Excellence (NICE) public health guidance (NICE 2012) as follows: No evidence (studies without any evidence of CEA); Weak evidence (one study only, or two studies that show consistent results, where at least one of them score a [+] overall study quality rating); Inconsistent evidence (more than one study where the results do not agree); and Moderate evidence (two or more studies where at least two of them score a [++] overall study quality rating, and results are all consistent).

RESULTS

Electronic searches identified 1,391 records. An additional 113 records were obtained through the grey literature and by snowballing. After removing duplicates, 1,021 records were screened by title and abstract and 24 potentially relevant articles were identified for full-text review. Of these, 18 were excluded, leaving six studies included in the review. Table A2 shows the characteristics of these excluded studies. No additional relevant articles by the first author search of included papers were found in the additional search in MEDLINE (Figure 1).

Following critical appraisal, one study (Esperato et al. 2012) was given a [-] overall study quality rating due to the very limited reporting of the study methods and analysis regarding CEA, rather than concerns regarding poor study design or missing data. The Esperato et al. (2012) study was consequently excluded from further data extraction and synthesis.

Synthesis of Results

The aim, setting, methods, interventions and road users studied in the remaining five papers are summarised in Table A3. The included studies were published between 2006 and 2013 and were from China (Bishai and Hyder 2006; Stevenson et al. 2008), Uganda (Bishai et al. 2008), Thailand (Ditsuwan et al. 2013), and WHO Sub-Saharan Africa (SSA) and SEA regions (Chisholm et al. 2012).

The economic characteristics of the five included studies are summarised in Table A4. All studies expressed the CEA of intervention in the form of a cost per DALYs averted except Bishai et al. (2008) who measured cost per life-year saved. Of five studies, three were undertaken from a societal perspective (Bishai and Hyder 2006; Chisholm et al. 2012; Stevenson et al. 2008) and one study each from the police department (Bishai et al. 2008) and health sector perspective (Ditsuwan et al. 2013). All studies except Ditsuwan et al. (2013) did not state the discount rate, or conduct sensitivity analyses. Three out of five studies had a time horizon of one year (Bishai and Hyder 2006; Ditsuwan et al. 2013; Stevenson et al. 2008), one study had time horizon of 10 years (Chisholm et al. 2012), and one was unreported (Bishai et al. 2008). All future costs and consequences (DALYs and/or life year saved) were discounted to present values at an annual rate of 3% by the studies that reported discounting in their studies (Bishai and Hyder 2006; Bishai et al. 2008; Chisholm et al. 2012; Ditsuwan et al. 2013).

Incremental Cost-Effectiveness Ratios (ICERs) were undertaken by three studies. Stevenson et al. (2008) measured ICERs with the net costs and benefits of comprehensive seatbelt interventions compared with no interventions to promote seat belt use. Chisholm et al. (2012)

reported ICERs briefly in the table with no numerical value of ICERs provided. Ditsuwan et al. (2013) compared the ICER of each intervention with willingness-to-pay thresholds of one and three times GDP per capita for one DALY.

The cost-effectiveness of interventions to prevent RTIs in LMICs ranged from US\$4.14 per DALYs averted for building speed bumps at the most dangerous junctions that caused 10 percent of junction deaths in the area studied, to US\$3,403 per DALYs averted for legislation and enforcement of helmet use by motorcyclists in the WHO sub-Saharan Africa region. The reporting of evidence of cost-effectiveness by included studies was expressed as either cost-effective or very cost-effective. A brief description of these interpretations as reported in the included studies is shown in Table A5.

Nine interventions were explored across the five included studies.

- 1. Traffic safety enforcement:** *Evidence statement*— There was weak evidence from two CEAs of traffic safety enforcement in the urban and rural areas of LMICs (Bishai and Hyder 2006 [+]) and Kampala, the capital of Uganda (Bishai et al. 2008 [+]), which showed that at 3% discount rate, the intervention was cost-effective. It is important to note, however, that Bishai and Hyder (2006) measured cost-effectiveness in terms of cost per DALYs averted using a societal perspective while Bishai et al. (2008) measured it in terms of cost per life year saved, from a police perspective.
- 2. Speed bumps installation:** *Evidence statement*— There was weak evidence of cost-effectiveness from one economic evaluation of speed bumps installation in the urban and rural areas of LMICs, which showed that in the short-term (time horizon of one year) and

at 3% discount rate, the intervention was considered very cost-effective (Bishai and Hyder 2006 [+]).

- 3. Bicycle helmet legislation and enforcement:** *Evidence statement*— There was weak evidence from two modelling studies that estimated cost-effectiveness analyses of bicycle helmet legislation and enforcement in the urban and rural areas of China (Bishai and Hyder 2006 [+]) and in the WHO SSA and SEA region (Chisholm et al. 2012 [++]), showing that at 3% discount rate, this intervention was cost-effective. It is important to note, however, that the interventions targeted children of different ages. The study by Bishai and Hyder (2006) [+] targeted ‘older’ children (age not stated) while the study by Chisholm et al. (2012) [++] targeted children under 15 years. Differences in sensitivity analyses and the time horizon used in these studies are shown in Table A4.
- 4. Motorcycle helmet legislation and enforcement:** *Evidence statement*— There was weak evidence from two modelling studies that estimated cost-effectiveness analyses of motorcycle helmet legislation and enforcement in the urban and rural areas of China (Bishai and Hyder 2006 [+]) and in the WHO SSA and SEA region (Chisholm et al. 2012 [++]), which showed that at 3% discount rate, this intervention was cost-effective. Differences in sensitivity analyses and the time horizon used in these studies are shown in Table A4.
- 5. Speed limit enforcement (via mobile speed cameras:** *Evidence statement*— There was weak evidence from one modelling study that estimated cost-effectiveness analyses of speed limit enforcement via mobile speed cameras in the urban and rural areas of the WHO SSA and SEA region which showed that at 3% discount rate, this intervention was

cost-effective for the SSA region and very cost-effective for the SEA region (Chisholm et al. 2012 [++]).

- 6. Drink-drive legislation and enforcement (via breath testing campaigns):** *Evidence statement*— There was moderate evidence from two modelling studies that estimated cost-effectiveness analyses of breath testing enforcement in the urban and rural areas of the WHO SSA and SEA regions (Chisholm et al. 2012 [++]) and in Thailand (Ditsuwan et al. 2013 [++]), which showed that at 3% discount rate, this intervention was cost-effective. Both these studies conducted probabilistic uncertainty analysis, however, each used a different time horizon and perspective (see Table A4).
- 7. Mass media campaign to reduce drink-driving:** *Evidence statement*— There was weak evidence from one modelling study that estimated cost-effectiveness analyses of mass media campaign to reduce drink-driving in the urban and rural areas of Thailand. At 3% discount rate, the study found that the mass media campaign was very cost-effective (Ditsuwan et al. 2013 [++]).
- 8. Seatbelt legislation and enforcement:** *Evidence statement*— A modelling study by Chisholm et al. 2012 [++] showed weak evidence that analysis of seatbelt legislation and enforcement in urban and rural areas of the WHO SSA and SEA regions was cost-effective.
- 9. Combined interventions for reducing RTIs:** *Evidence statement*— Three cost-effectiveness analyses provided moderate evidence that combined interventions for reducing RTIs in urban and rural areas of the WHO SSA and SEA regions (Chisholm et al. 2012 [++]), in urban and rural areas of Thailand (Ditsuwan et al. 2013 [++]), and in an

urban area of China (Stevenson et al. 2008 [+]) were cost-effective. The interventions in these programmes varied significantly with two (Chisholm et al. 2012; Ditsuwan et al. 2013) evaluating mixed RTI interventions, and one (Stevenson et al. 2008) exploring a comprehensive seatbelt programme. In addition, the studies varied in the sensitivity analyses, discount rate, time horizon, and the perspective chosen (see Table A4).

DISCUSSION

This review found that overall there is limited and relatively weak evidence regarding the CEA of interventions to prevent RTIs in LMICs. The strength of evidence was based on the quality, quantity and consistencies of the included studies in the review. The quality of the CEA studies as assessed against published criteria (Evers et al. 2005) was relatively poor. There were relatively few studies available meeting the inclusion criteria, and together they analysed the cost-effectiveness of only nine interventions. This finding supports that of Anderson and Shemilt (2010) who stated that there was a relative paucity of CEA studies as a whole in health care in developing countries more than five years ago. In addition, there was significant variation in how authors chose to report the CEA of the interventions, specifically the consideration of perspective, time horizon, discount rate and sensitivity analyses differ significantly among studies. No evidence of cost-effectiveness was found for a number of interventions reported to have the potential to improve road safety; safe road infrastructure, safe vehicles, safe walking and safe cycling (Peden et al. 2004, WHO 2015).

We identified only two interventions (bicycle and motorbike helmet legislation) targeted to vulnerable road user groups such as pedestrians, cyclists, and motorcyclists, and none

specifically targeted to children and young people. The Global Status Report on Road Safety states that road infrastructure in LMICs is mainly built with the needs of motorists in mind (WHO 2015) and it is disappointing to find such limited evidence to protect the most vulnerable despite now being more than half way through the Decade of Action for Road Safety 2011-2020 (WHO 2011). Success in improving safety for vulnerable road user groups, children, and young people is most likely to be achieved through a holistic approach, that considers the behaviour of all road users, the road environment and vehicle design to protect both vehicle occupants and those at risk outside the vehicle (OECD 2004). The safe systems approach (Peden et al. 2004) moves away from the idea that children and youth should adapt their behaviour to cope with traffic, but recommends that children's and young people needs should be addressed in the design and management of the whole road system. We were unable to identify any cost-effectiveness studies of such approaches in LMICs in this review.

Outcome Variability

We noted marked heterogeneity in how authors considered perspective, time horizon, discount rate and sensitivity analyses. Perspective refers to the viewpoint adopted in an economic analysis and may be that of government, the health system or provider, third-party payers, individuals or society (Abdelhamid and Shemilt 2010; Drummond et al. 2005; Shemilt et al. 2011). An intervention considered cost-effective from one perspective will not necessarily be cost-effective from another perspective. Given the impacts of perspective can have on judging an intervention as cost-effective, Byford and Raftery (1998) suggested to adopt the societal perspective for health interventions since health economics is concerned with society's welfare.

Health economists argue that time horizon could be shorter or longer than lifetime depending on health conditions (NICE 2012). It is recommended to be long enough to include all related costs and outcomes relating to the intervention. The use of a 3% discount rate in the included studies is consistent with one of the two conventions in choosing a discount rate, i.e. 3% and 5% (Smith and Gravelle 2001), although some argue that a sensitivity analysis considering both is helpful (Drummond et al. 2005).

Sensitivity analysis is an important feature of economic evaluations, particularly in decision-analytic modelling studies (Marsh 2010). Probabilistic sensitivity analysis also known as probabilistic uncertainty analysis is now popular in decision-analytic modelling studies because of its potential to support decision-makers in selecting most cost-effective interventions under conditions of uncertainty (Drummond et al. 2005). Although four out of five included studies in this review were modelling designs (Bishai and Hyder 2006; Bishai et al. 2008; Chisholm et al. 2012; Ditsuwan et al. 2013), only two conducted a probabilistic uncertainty analysis (Chisholm et al. 2012; Ditsuwan et al. 2013). A one-way sensitivity analysis was also conducted by Chisholm et al. (2012) on some variables for which particular uncertainty exists (e.g. proportion of vehicles stopped each year at a checkpoint, the effect size for bicycle helmets, and the cost of fitting seatbelts in a proportion of the motor vehicle fleet).

Study Strengths and Limitations

This review applied a comprehensive search strategy to 12 electronic databases with the aim to identify all studies meeting pre-specified criteria that were critically appraised prior to a synthesis using a recognised system of graded evidence statements. We acknowledge that further

studies meeting the inclusion criteria may exist. A major limitation of the study is that the review was limited to cost-effectiveness analyses and did not consider alternative methods of economic evaluation such as cost-utility analysis or cost-benefit analysis which also consider both costs (resource use) and consequences (outcomes, effects). The decision to limit the review to CEA studies may have resulted in the absence of studies using Value of Statistical Life as an outcome. The study was restricted to studies published in the English language due to lack of resources for translation which may have resulted in the exclusion of eligible studies.

We were faced with the challenge of needing to assign the interventions as ‘cost-effective’ or ‘very cost-effective’. There are many thresholds for the cost-effectiveness of interventions in the literature (e.g. thresholds based on per capita national incomes, benchmark interventions and league tables), each with their own weakness (Eichler et al. 2004; Marseille et al. 2015) and subject to judgement. Therefore, by converting all the costs to US\$2013 per DALYs averted, the findings are more comparable and decision makers can choose the cost-effectiveness thresholds that will be appropriate to their settings. Despite the evidence of the CEA of interventions to prevent RTIs in LMICs identified, it is not appropriate to generalise these findings across different country/population contexts of LMICs due to the limited range of countries from which the evidence has arisen, the fact that most evidence arose from urban rather than rural settings and the inconsistency in evidence identified between studies.

Implications for Public Health Practice, Policy and Research

This study supports the finding that there continues to be a paucity of comprehensive cost-effectiveness evidence to support the adoption and implementation of interventions in LMIC

settings that have been shown to prevent injuries due to road traffic (Staton et al. 2016; Wesson et al. 2014). We have illustrated the need for further studies that explore outcomes specifically for children, young people and vulnerable road users. There are many reasons why it is difficult and often inappropriate to generalise findings from one country to another. The most obvious reason is that there are marked differences within and between countries in terms of basic demography, epidemiology of RTIs, risk factors for RTIs, vehicles and their density, different road user groups, availability of existing road safety interventions, relative prices or costs of the interventions which have important implications for interventions applicability (Drummond et al., 2005; Walker et al., 2010). For instance, the majority of RTIs in South East Asia involve motorcycle riders and occupants whereas in African regions it is vehicle occupants and pedestrians who are the victims of injury. In this case, motorcycle helmet use legislation and enforcement are likely to be more cost-effective in South East Asia region where the number of motorcycle users is high. For countries to adopt intervention programmes, they will require evidence that investing in these programmes is likely to result in both reduced injuries and cost effectiveness, particularly where programmes are to be implemented in countries and settings beyond those where studies have been conducted. Researchers are encouraged to consider the perspective, time horizon, discount rate, and the choice of sensitivity analyses before conducting an economic evaluation, as these influence both the quality of the economic evaluation, and facilitate comparisons with other similar interventions. In addition, the use of international dollars along with the currency of the country of study will enable comparison with other published studies.

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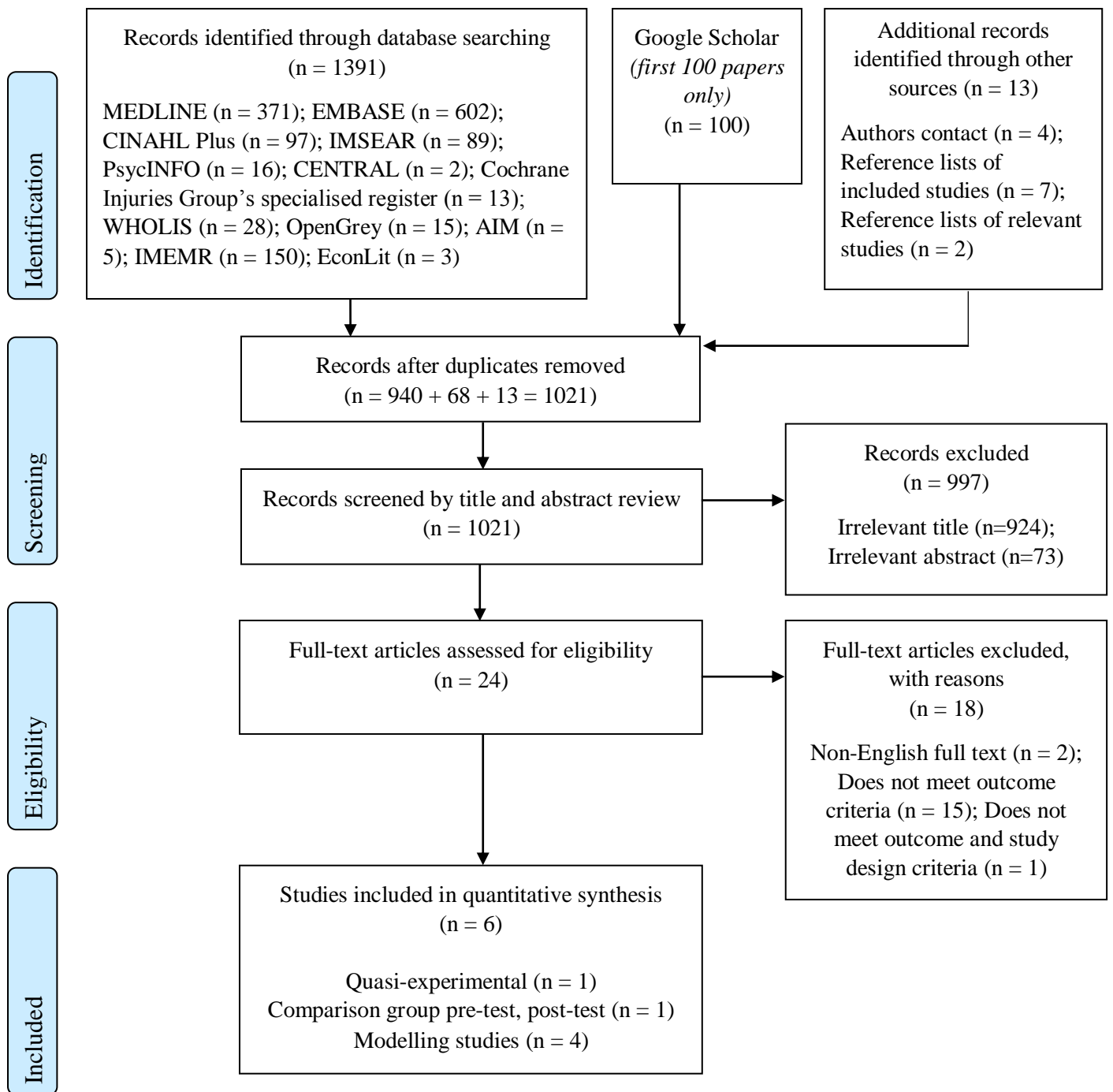


Figure 1. PRISMA - Style flow diagram