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Systematic review and quality assessment of economic evaluation studies of injury prevention

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ABSTRACT

Objective: To review and assess the quality of economic evaluation studies on injury prevention measures.
Design: Systematic review.
Data sources: Electronic databases searched included Medline (Pubmed), EMBASE, Web of Science, PsycINFO, and Safetylit.
Inclusion criteria: Empirical studies published in English in international peer-reviewed journals in the period 1998–2009. The subject of the study was economic evaluation of prevention of unintentional injury. Cost-effectiveness (CEA), cost-benefit (CBA) and cost utility (CUA) analyses were included.
Methods: Methodological details, study designs, and analysis and interpretation of results of the included articles were reviewed and extracted into summary tables. Study quality was judged using the criteria recommended by the Panel on cost-effectiveness in health and medicine and the British Medical Journal (BMJ) checklist for economic evaluations.
Results: Forty-eight studies met the inclusion criteria of our review. Interventions assessed most frequently were hip protectors and exercise programs for the elderly. A wide variety of methodological approaches was found, including differences in type of economic evaluation, perspective, time horizon, study design, cost categories, effect outcomes, and adjustments for timing and uncertainty used. The majority of studies performed a cost-effectiveness analysis from a societal perspective with a time horizon of one to five years, in which the effect was expressed in terms of injuries prevented and only direct health care costs were included. Most studies deviated from one or more of the Panel recommendations or BMJ guidelines; e.g. not adopting the societal perspective, not including all relevant costs, no incremental analysis.
Conclusions: This review has shown that approaches to economic evaluation of injury prevention vary widely and most studies do not fulfill methodological rigour. Improving quality and harmonization of economic evaluation studies in the field of injury prevention is needed. One way of achieving this would be to establish international guidelines on economic evaluation for injury prevention interventions, based on established economic evaluation checklists, to assist researchers in the design and reporting of economic evaluations.

1. Introduction

Injuries result in a high disease burden in terms of deaths and disability (Murray and Lopez, 1997; Krug et al., 2000; Morrison et al., 2000). They have been widely recognized as a major public health problem, and much health benefit can be gained by implementing injury prevention interventions. The injury problem is large and heterogeneous (Polinder et al., 2007), regarding to external cause, injury type, severity, age patterns, and possibilities for prevention.

In setting priorities for injury prevention and allocating scarce resources between alternative uses, choices must be made (Hendrie and Miller, 2004). For example, should more resources be allocated to falls prevention programs for the elderly, water safety programs for children, or helmet wearing programs for adolescents? Within the falls prevention area, should more resources be allocated to

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reducing the current rate of falls by screening elderly fallers visiting the emergency department (high-risk population) or to provide an information campaign for all persons above 55 (low-risk population) (Hendrie and Miller, 2004)?

To maximize the effectiveness of their injury prevention policy in terms of health outcome and efficient spending of resources, objective methods are needed that guide these choices (Drummond et al., 2005). It is widely argued that economic evaluation studies should play a role in health care priority-setting, since they provide information on those interventions with the most favourable balance between costs and health effects (Drummond et al., 2005). In general, there are four different types of economic evaluations: cost-minimization analysis (CMA), cost-effectiveness analysis (CEA), cost–benefit analysis (CBA), and cost-utility analysis (CUA) (see Table 1) (Gold et al., 1996; Drummond et al., 2005). In comparing two interventions designed to address the same health problem, CMA searches for the least costly alternative that produces the same health benefit. CEA, by contrast, compares the per unit effect with the per unit cost on an incremental basis of two different health interventions and CBA measures both the costs and consequences of two or more alternative interventions in terms of the potential money gained or saved compared to the money invested in the intervention. Lastly, CUA employs utilities (e.g., quality adjusted life-years or QALYs) as the outcome measure to compare and evaluate two or more interventions incrementally. CUA attempts to translate the health outcomes of all interventions into a single outcome measure (e.g., QALYs) in efforts to compare the added value of one program versus another on the same outcome scale.

Some reviews targeting the economic evaluation of different injury prevention interventions have been conducted. Recently, a review was published on cost-effectiveness studies of municipality based injury prevention interventions (Gyllensvard, 2010). The results indicated that there are injury prevention interventions that offer good use of societal resources, but that there is lack of economic evidence surrounding injury prevention interventions. Furthermore, a review on the cost-effectiveness of interventions in reducing the risk of new falls, or modifying the harm caused in the event of a fall of elderly living independently in the community, was performed (Smith and Fordham, 2001). Both previous reviews were restricted to either a specific setting (Gyllensvard, 2010) or to a specific target group (Smith and Fordham, 2001), but a systematic review of economic evaluations covering the full spectrum of preventing unintentional injury has not been conducted yet. League tables of CEA estimates for injury prevention do exist, however, notably Miller and Levy (2000) and Miller et al. (2005) scattered through the Tufts CEA registry, with a wider selection and comparison to estimates for other sectors.

For priority setting in the heterogeneous field of unintentional injury prevention, there is a high demand for economic evaluation studies according to a high-quality 'state-of-the-art' method. Economic evaluation studies of injury prevention measures will gain value when they are of high quality and use comparable methods across the field that are in line with the methodology used for other public health issues. Hence, it is important to compile the existing economic evidence to reveal which methodological approaches are currently used within the injury field. The purpose of this paper is to present the results of a systematic review of the peer reviewed literature and to critically assess the quality of economic evaluations of injury prevention programs.

2. Methods

2.1. Data sources and search strategy

Searches of eligible studies were conducted in Medline (PubMed), Web of Science, Embase, PsychInfo, and SafetyLit. All international peer-reviewed articles published in the period January 1998 to December 31st, 2009 and compiled through these search engines were included. Search terms used were: 'wounds and injuries', 'accidents', 'costs and cost analysis', 'economic evaluation', 'cost effectiveness', 'cost benefit', 'cost utility', 'prevention', 'primary prevention', 'secondary prevention', and 'accident prevention'. Keywords were matched to database specific indexing terms in collaboration with a librarian. In addition to database searches, reference lists of review studies and articles included in the review were screened for titles that included key terms.

2.2. Selection criteria

In this review CEA, CBA and CUA studies of primary or secondary prevention of unintentional injuries were included. Only empirical studies published in English in a peer reviewed journal that we could readily access were included. Studies of non-established market economies (e.g. (Waters et al., 2004; Scuffham, 2008)) as defined by the World Bank (WHO-EURO region) are excluded.

Studies were included on the basis of the following definition of injuries: 'An injury is the damage caused by the acute transfer of energy, whether physical, thermal, chemical or radiant, that exceeds the physiological threshold, or by the deprivation of a vital element'. Injuries can be unintentional such as those related to most road traffic injuries, burns or scalds, falls, poisoning and drowning or submersion, or they can be intentional, such as those due to interpersonal, self-directed or collective violence. In this review only unintentional injuries are included. Studies on natural disasters are excluded (e.g. (Simmons and Sutter, 2006)). Injury prevention concerns a group of interventions that aim at breaking through the chain of events that lead to an injury (Mackenbach, 2008), with the aim to reduce the incidence of injuries, their severity, and their costs. The focus of this paper has been primary prevention (reducing the incidence) and secondary prevention (reducing the damage caused by reducing the acute transfer of energy, e.g. hip protectors or helmets).

Studies were excluded if they fell out of the scope of unintentional injury (e.g. violence), did not fulfill the criteria of a full economic evaluation (e.g. cost-minimalisation studies), if other than preventive measures were evaluated (e.g. health care interventions), or if they focused on methodological issues and/or no outcomes were reported.

2.3. Data extraction

Relevant papers were selected by screening the titles (first step), abstracts (second step) and entire articles (third step). During each step respectively the title, abstract or entire article was screened to ensure that it met the selection criteria listed above. Screening of the articles was conducted independently by two researches (S.P. and E.B.). Disagreement about eligibility between the researchers was solved through discussion. Full articles were extracted by the 2 researchers (S.P. and E.B.) for methodological details, study designs, and analysis and interpretation of results into summary tables.

2.4. Quality assessment

Assessment of the quality of the economic evaluations was based on the checklist for reporting reference-case cost-utility analyses recommended by the Panel on cost-effectiveness in health and medicine (Gold et al., 1996) and on guidelines developed for economic submissions to the British Medical Journal (BMJ). It was also consistent with the data auditing form developed by researchers at the Harvard Center for Risk Analysis (available at: http://www.hsph.harvard.edu). These checklists were processed in

Table 1
Overview of economic evaluation methods.

Type of study	Measurement of benefits	Economic summary measure
Cost-minimalisation	No measure of effects, since they are equal	Net cost or cost of illness
Cost-effectiveness	Natural units (e.g. life years gained, burns prevented)	Cost-effectiveness ratio, cost per case averted, cost per life year saved
Cost-benefit	Monetary units	Net benefit or cost benefit-to-cost ratio
Cost-utility	Healthy years (e.g. quality adjusted life years (QALY))	Cost per QALY

a template as shown in Table 2, which was filled in for all included papers by two reviewers (S.P. and E.B.).

3. Results

3.1. Literature search

The database search identified 788 titles in Medline (Pubmed) and 187 additional papers in Embase (77), Psychinfo (55), Web of Science (55), and SafetyLit (22) resulting in 997 unique titles of potentially relevant articles. Screening of the titles and abstracts resulted in a selection of 101 articles that appeared to meet all selection criteria. Fifty-three of these articles did not meet the inclusion criteria after the paper had been fully read, resulting in final inclusion of 48 articles. The reasons of exclusion of the 53 full papers were not being a full economic evaluation ($n = 20$), no injury prevention ($n = 22$), no empirical study ($n = 10$) or no established market economy ($n = 1$).

3.2. Study descriptions

More than half of the studies included concerned primary injury prevention ($n = 27$, see Table 3). One study concerned primary as well as secondary prevention interventions (Zaloshnja et al., 2003). Single-component interventions were assessed more frequently than multi-facet interventions ($n = 33$ versus $n = 12$). Often, multi-facet interventions are based on primary prevention programs (Smith and Widiatmoko, 1998; Salkeld et al., 2000; Lindqvist and Lindholm, 2001; Zaloshnja et al., 2003; Miller et al., 2004, 2007; Spicer et al., 2004; Beard et al., 2006; Viamonte et al., 2006; Han et al., 2007; Spetz et al., 2007; Johansson et al., 2008). Interventions most frequently targeted prevention of home and leisure injuries ($n = 22$) and traffic related injuries ($n = 15$). Four interventions targeted prevention of occupational injuries, of which three aimed at the prevention of tractor overturn-related injuries (Pana-Cryan and Myers, 2000; Day et al., 2004; Myers et al., 2004). The intervention that targeted prevention of sports injuries aimed at the prevention of ankle sprains (Verhagen et al., 2005) and face protection for hockey players (Woods et al., 2008) (see Table 3). The most common patient group for economic evaluation due to home and leisure injuries relates to fall prevention in elderly people ($n = 18$, see Table 3). Interventions assessed most frequently were hip protectors ($n = 8$) and exercise programs for elderly ($n = 5$) (Table 3).

Table 2
Summary of criteria for assessing quality of economic evaluations.*

- Framing
  - Comparator intervention
  - Study perspective
  - Modelling assumptions and diagram
  - Discounting
- Costs
  - Reporting of direct and indirect costs
  - Reporting of net costs
  - Costing source
  - Costs reported in single year
- Effects
  - Health outcomes stated
  - Preferences and source stated
- Results
  - Incremental cost-effectiveness ratios
  - Sensitivity analyses
- Discussion
  - Study limitations
  - Comparison with other studies

* From the checklist for reporting reference-case cost-utility analyses recommended by the Panel on Cost-Effectiveness in Health and Medicine and guidelines for economic submissions to the BMJ; also consistent with the data auditing form developed by researchers at the Harvard Center for Risk Analysis.

3.3. Assessing economic evaluation quality

3.3.1. Framing

The studies differed significantly in terms of economic study type and main assumptions. In the majority of the studies a CEA ($n = 18$) or CBA ($n = 17$) was performed (Table 4). There were also eight studies that performed both a CEA and a CUA or CBA. In total, nine studies performed a CUA (Redelmeier and Weinstein, 1999; Segui-Gomez et al., 2002; Thompson et al., 2002; Colon-Emeric et al., 2003; Singh et al., 2004; Honkanen et al., 2006; Miller et al., 2006; Gandjour and Weyner, 2008; Johansson et al., 2008), most evaluating the use of hip protectors in the elderly. The research question being addressed should be clearly stated and the alternative interventions should be described in sufficient detail. In all articles the objective of the study was stated clearly, but most times a research question was not explicitly reported. There were only six studies that justified the choice of form of economic evaluation used (Zacker and Shea, 1998; Pana-Cryan and Myers, 2000; Robertson et al., 2001a; Taylor and Scuffham, 2002b; Beard et al., 2006; Hektoen et al., 2009).

The ultimate aim of an economic evaluation is to determine which option provides the best value of money. An incremental approach (i.e., how much health effect for one more unit of intervention) is generally adopted in which the additional costs that one alternative imposes over another is compared with the additional benefits provided, presented as an incremental cost-effectiveness ratio (ICER). Most articles gave a clear description of the alternatives, which could be alternative interventions or a control group without the intervention. In most economic evaluation studies a comparison is made between new interventions (e.g. hip protectors) compared to the standard situation.

From the papers that stated their perspective of analysis, the most common declared one was the societal perspective, taking into account costs and benefits to all members of society ($n = 33$, see Table 4). Furthermore, nine studies reported results from the health care system perspective only.

The period of study ranged from less than six months (Chen, 2005; Spetz et al., 2007) to a life time horizon (Segui-Gomez et al., 2002; Singh et al., 2004; Miller et al., 2006; Johansson et al., 2008). Most studies had a study time period of between one and five years ($n = 21$, Table 4). Four studies did not describe the study time period (Zacker and Shea, 1998; Ginnelly et al., 2005; Woods et al., 2008; Haines et al., 2009). In addition, costs of an intervention incurred in the future, or benefits received in the future, are argued to be of lesser value because money can earn interest when invested and the future is uncertain. The way of incorporating this phenomenon is to 'discount' future costs and benefits by giving less weight to

Table 3
Description of the intervention described in the included studies.

Study characteristics	Studies (*n*)	Study numbers (annex A)
Prevention type		
Primary	27	1, 2, 7, 9, 10, 11, 13, 14, 15, 18, 22, 23, 24, 26, 28, 30, 32, 33, 34, 35, 36, 37, 40, 41, 42, 45, 46
Secondary	20	3, 4, 6, 8, 12, 16, 17, 19, 20, 21, 25, 27, 29, 31, 38, 39, 43, 44, 47, 48
Primary and secondary	1	5
Single component/multi facet		
Single component	35	2, 3, 4, 6, 7, 8, 9, 10, 11, 12, 13, 15, 16, 17, 19, 20, 21, 22, 24, 25, 27, 29, 30, 32, 33, 34, 35, 36, 38, 39, 43, 44, 45, 47, 48
Multi facet	13	1, 5, 14, 18, 23, 26, 28, 31, 37, 40, 41, 42, 46
Interventions		
Hip protectors	8	6, 9, 16, 17, 21, 25, 38, 39
Exercise program	5	13, 15, 33, 34, 35
Patient safety	2	2, 41
Helmet use (bicycle/motor)	5	3, 8, 20, 30, 43
Home hazard reduction	2	37, 40
ROPS system	1	31
Energy absorbing flooring	1	48
Community education	2	18, 29
Safety councils	1	23
Car restraints	2	11, 19
Smoke alarms	2	12, 10
Speed reduction	1	4
Screening + licence renewal	1	46
Regulations + education	2	7, 9
PA + med + home modification	1	1
Community program	1	42
Stair-fall requirements	1	36
Black spot program	1	24
Breath testing + media campaign	1	26
Training + random testing	1	28
Alcohol ignition interlock	1	22
Booster seat	1	27
Cellular telephone regulations	1	32
Ankle sprain	1	45
Face protection hockey	1	47
Safety belts + street lights	1	5
Street lights	1	5
Drowning prevention	1	5
Suicide prevention	1	5
Airbag regulation	1	44
Injury type		
Home and leisure	22	1, 2, 6, 9, 10, 12, 13, 14, 15, 16, 17, 18, 21, 25, 33, 35, 37, 38, 39, 40, 41, 48
Fall-related injuries	11	1, 2, 13, 15, 33, 34, 35, 37, 40, 41, 36
Hip fractures	7	6, 9, 18, 25, 38, 39, 48
Scald injuries	1	14
Stair fall-related injuries	1	36
Fire-related injuries	2	12, 10
Traffic	15	3, 4, 8, 11, 19, 20, 22, 24, 26, 27, 30, 32, 43, 44, 46
Road traffic injuries	8	11, 19, 22, 24, 26, 27, 32, 44
Collision related injuries	2	4, 46
Head injuries	5	3, 8, 20, 30, 43
Occupational	4	7, 28, 29, 31
Tractor overturn injuries	3	7, 29, 31
Substance related injuries	1	28
Sports	2	45, 47
All	3	5, 23, 42

future events. In total, 25 studies reported using a discount rate to adjust for the present value of future costs and benefits (Table 4), most ranging between 3% and 6%. It was not always stated whether costs and benefits were discounted or only costs. Of the studies that did not use a discount rate, most had a short study time period; two studies with less than one year (Verhagen et al., 2005; Spetz et al., 2007) and thirteen studies with a time frame between 1-5 years (Table 4). However, most studies did not offer an explanation as to why costs or benefits were not discounted.

Most studies used a modelling approach to assess cost-effectiveness ($n = 24$, see Table 4). All nine cost-utility studies used a modelling approach and most of the decision analysis model studies had cost-effectiveness or cost-utility as primary outcome. Furthermore, nine of the studies used a randomised controlled trial (RCT) design, and ten studies were based on quasi-experimental designs (Table 4). Other designs used were meta-analyses (Smith and Widiatmoko, 1998; Kopjar and Wickizer, 2000), statistical surveys (Taylor and Scuffham, 2002a) and retrospective epidemiological designs (Boswell et al., 2001).

3.3.2. Costs

Costs can be distinguished into direct medical costs (e.g. hospital stay), indirect medical costs (e.g. costs of care during life years gained), direct non-medical costs (e.g. traveling costs), and indirect non-medical costs (e.g. productivity loss). A majority of studies ($n = 27$) only included direct medical costs (Table 5). Only three studies included both direct medical costs and indirect costs inside and outside the health care sector (Miller et al., 2004; Myers et al., 2004; Rodgers and Leland, 2008) (Table 5).

Table 4
Framing of the study: number of studies by economic evaluation characteristics.

Study characteristics	Studies (*n*)	Study numbers (annex A)
Type of economic evaluation		
Cost-effectiveness analysis (CEA)	18	7, 9, 11, 13, 15, 19, 20, 21, 28, 29, 30, 33, 34, 35, 37, 40, 41, 45
Cost-benefit analysis (CBA)	17	1, 2, 3, 4, 8, 10, 12, 16, 22, 23, 24, 28, 36, 26, 42, 46, 47
Cost-utility analysis (CUA)	5	9, 17, 18, 32, 44
CEA + CUA	2	38, 39
CEA + CBA	4	5, 31, 43, 48
CBA + CUA	2	6, 27
Design		
Meta analysis	2	20, 40
RCT	9	10, 25, 31, 33, 34, 35, 37, 41, 45
Quasi-experimental design	10	1, 4, 7, 12, 13, 15, 19, 23, 42, 47
Statistical survey	1	43
Modelling study	24	3, 6, 8, 9, 11, 14, 16, 17, 18, 21, 22, 24, 25, 26, 27, 28, 30, 32, 36, 38, 39, 44, 46, 48
Retrospective epidemiological design	1	2
Descriptive	1	5
Economic perspective		
Societal (SOC)	28	5, 6, 7, 8, 11, 16, 18, 20, 22, 23, 25, 27, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 43, 44, 45, 48
Health care (HC)	10	2, 3, 10, 13, 15, 21, 41, 42, 46, 47
Insurance (INS)	1	17
Governmental (GOV)	2	14, 24
SOC + INS	3	4, 9, 19
SOC + HC	2	1, 12
SOC + GOV + IND	1	26
Individual + SOC	1	28
Time horizon		
< = 1 year	4	6, 15, 41, 45
1–5 years	21	1, 2, 3, 4, 5, 6, 7, 12, 16, 17, 19, 21, 23, 24, 25, 26, 33, 34, 35, 37, 42
5–10 years	5	8, 11, 20, 43, 46
10–50 years	10	7, 14, 22, 28, 29, 30, 31, 32, 40, 44
Life time	4	18, 27, 38, 39
Not described	4	10, 13, 47, 48
Discounting		
Yes	25	4, 5, 7, 9, 11, 12, 14, 16, 17, 18, 20, 22, 24, 27, 28, 29, 30, 31, 32, 36, 38, 40, 43, 44, 48
No	23	1, 2, 3, 6, 8, 10, 13, 15, 19, 21, 23, 25, 26, 33, 34, 35, 37, 39, 41, 42, 45, 46, 47
Sensitivity analysis economic evaluation		
Yes	34	4, 5, 6, 9, 10, 11, 12, 13, 14, 16, 18, 20, 22, 24, 25, 27, 28, 29, 30, 31, 32, 33, 34, 36, 37, 38, 39, 40, 41, 43, 44, 45, 48
No	14	2, 3, 7, 8, 15, 17, 19, 21, 23, 26, 35, 42, 46, 47

The chosen perspective determines which cost categories should be included in the analysis. Preferably, in a societal perspective cost analysis takes direct and indirect costs inside and outside the health care sector into account. Of the 35 studies described as having performed an economic evaluation from a societal perspective, 15 studies only included direct medical costs (Smith and Widiatmoko, 1998; Kopjar and Wickizer, 2000; Salkeld et al., 2000; Robertson et al., 2001a,b; Segui-Gomez et al., 2002; Colon-Emeric et al., 2003; Day et al., 2004; Singh et al., 2004; Honkanen et al., 2005; Meyer et al., 2005; Eastridge et al., 2006; Gandjour and Weyner, 2008; Robertson et al., 2008). There were only 4 studies with a societal perspective that included all cost categories (Miller et al., 2004; Myers et al., 2004; Rodgers and Leland, 2008; Myers et al., 2009). All studies performed from a health care, insurance or government perspective (see Table 4) included only direct costs within the health care sector, which is in accordance with economic evaluation guidelines (Gold et al., 1996; Drummond et al., 2005).

A wide diversity exists across the studies in the inclusion of cost components for calculating the costs of injuries and costs of the intervention (see Table 5). For example, 37 studies estimated intramural costs, but the cost components included – such as hospitalization, medical treatment, emergency department visits and outpatient hospital care – varied widely. Furthermore, eleven studies calculated productivity loss as part of indirect non-medical costs. There were also eight studies that did not include the costs of the intervention in the cost calculations (Table 5).

Almost all studies (except (Kumar and Parker, 2000; Salkeld et al., 2000; Robertson et al., 2001a; Spetz et al., 2007)) delivered information about the data source of the unit costs used, of which fourteen studies also recorded the currency and price data. The sources of health care resources (or effectiveness estimates) used were stated in 18 studies (see Table 5).

3.3.3. *Effect outcomes of CEA and CUA studies*

All studies have clearly defined the effect outcome measure. Within the different forms of economic evaluation (CEA and CUA), the used outcome measures were quite comparable. The effectiveness estimate of a CEA study is often based on the percentage reduction in incidence or harm. The effects of the described interventions in CEA studies were expressed in terms of injury prevented (Smith and Widiatmoko, 1998; Zacker and Shea, 1998; Kopjar and Wickizer, 2000; Kumar and Parker, 2000; Pana-Cryan and Myers, 2000; Taylor and Scuffham, 2002a; Myers et al., 2004; Singh et al., 2004; Verhagen et al., 2005; Han et al., 2007; Haines et al., 2009; Myers et al., 2009), fall prevented (Salkeld et al., 2000; Robertson et al., 2001a,b; Spetz et al., 2007; Robertson et al., 2008; Hektoen et al., 2009) or life saved (Segui-Gomez et al., 2002; Day et al., 2004; Kedikoglou et al., 2005; Goldstein et al., 2008). The effects are generally estimated using statistical modelling, but are also often inferred from studies of similar programs by others. All nine CUA studies reported outcomes in terms of quality adjusted life years (QALYs) but information on the valuation of health states was not specified in all studies. In five of these studies disability weights were derived from multi-attribute utility instruments (MAUI), such as the EQ-5D (Singh et al., 2004; Gandjour and Weyner, 2008; Johansson et al., 2008), the Health Utility Index (Honkanen et al., 2006), or the Functional Capacity Index (Redelmeier and Weinstein, 1999; Segui-Gomez et al., 2002). Two studies based their QALY on values

Table 5
Number of studies by study characteristics reported.

Study characteristics	Studies (*n*)	Study numbers (annex A)
Cost categories[a]		
DCH	27	2, 3, 5, 6, 7, 8, 9, 13, 14, 15, 16, 17, 18, 20, 21, 24, 25, 33, 34, 35, 37, 38, 39, 40, 42, 41, 46
DCH + DCO	8	4, 10, 11, 22, 27, 32, 44, 47
DCH + ICO	6	12, 19, 23, 28, 43, 45
DCH + ICH	3	1, 31, 48
DCH + ICO + ICH	4	26, 29, 30, 36
Cost components		
Intervention	40	1, 2, 4, 6, 7, 9, 10, 11, 12, 15, 16, 17, 18, 19, 20, 22, 24, 25, 26, 27, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48
Intramural costs	34	
Hospitalization	34	2, 3, 6, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 21, 23, 24, 25, 26, 27, 30, 32, 33, 34, 36, 37, 38, 39, 40, 41, 42, 43, 45, 46
Administrative	1	35
Medical treatment	11	9, 10, 11, 12, 15, 20, 24, 30, 32, 36, 42
Emergency department	11	1, 10, 11, 14, 15, 30, 33, 34, 36, 38, 43
Outpatient hospital care	7	2, 6, 9, 10, 14, 15, 26
Extramural care (e.g. GP, physiotherapist)	11	11, 15, 20, 23, 25, 33, 34, 37, 40, 45, 47
Ambulance transport	10	8, 10, 11, 12, 15, 25, 26, 32, 36, 40
Nursing residence	6	5, 9, 16, 17, 40, 48
Rehabilitation	8	3, 9, 11, 15, 16, 26, 32, 38
Medication and medical devices	7	11, 14, 19, 25, 29, 35, 45
Productivity loss	11	11, 12, 19, 23, 26, 27, 29, 30, 36, 43, 45
Insurance claims	2	4, 36
Travel costs	4	32, 33, 34, 35
Time costs	1	17
Availability information calculation costs[b]		
Data source unit costs (A)	20	1, 2, 3, 4, 7, 8, 11, 12, 14, 16, 17, 20, 26, 28, 36, 37, 38, 39, 42, 47
Data source and prices (A + B)	9	9, 13, 22, 24, 27, 30, 31, 45, 46
Data source, prices and resources (A + B + C)	14	6, 10, 15, 18, 19, 25, 29, 32, 34, 35, 40, 43, 44, 48
Prices and resources (B + C)	2	33, 41
Data source and resources (A + C)	2	5, 16
None	1	21

[a] DCH = direct costs within health care sector, ICH = indirect costs within health care sector, DCO = direct costs outside the health care sector, ICO = indirect costs outside the health care sector.
[b] Information available in manuscript about data source unit costs (A), currency and price data (B), (health care) consumption (resources) (C).

using the 'Time Trade-Off' technique (Colon-Emeric et al., 2003; Honkanen et al., 2006).

3.3.4. Adjustments for timing and uncertainty analysis and interpretation of results

Every economic evaluation contains some uncertainty as a result of possible imprecision in the parameter values used or methodological controversy regarding economic evaluation. This uncertainty is dealt with using sensitivity analysis, which tests whether plausible changes in values of the main variables affect the results of the analysis (Mcclure et al., 2004). Of all included studies, 34 studies performed a sensitivity analysis to examine the results with varying assumptions, often by estimating the standard error or 95% confidence interval around the CEA estimate. Most studies showed how the results of their study vary when the intervention effectiveness differs (e.g. (Smith and Widiatmoko, 1998; Zacker and Shea, 1998; Haddix et al., 2001; Segui-Gomez et al., 2002; Singh et al., 2004; Spetz et al., 2007; Meuleners et al., 2008; Rodgers and Leland, 2008)) and some studies show also the effect when a discount rate changes (e.g. (Smith and Widiatmoko, 1998; Zacker and Shea, 1998; Robertson et al., 2001b; Gandjour and Weyner, 2008; Johansson et al., 2008; Rodgers and Leland, 2008; Lahausse and Fildes, 2009)). Rarely the choice of variables for sensitivity analysis is justified (e.g. (Smith and Widiatmoko, 1998; Singh et al., 2004)).

3.3.5. Findings and interpretation of results

Most of the included articles reported a favourable outcome of the economic evaluation. However, there are some CEA studies reporting an unfavorable outcome (e.g. (Meyer et al., 2005; Verhagen et al., 2005; Spetz et al., 2007; Robertson et al., 2008)). Six CUA studies analyzed hip protectors, of which five found that the intervention is more effective but more costly. In a league table we have shown the ICER of these studies (Table 6). Some studies suggest that women profit from the use of hip protectors at an earlier age than men do. Commonly, the studies can make an adoption decision by comparing an intervention's cost-effectiveness ratio or net monetary benefit to a predefined standard (i.e., a maximum acceptable cost-effectiveness ratio or willingness to pay), for example €30,000 or €50,000 per QALY. Of the reviewed articles, two CUA studies used a threshold of $50,000 (€36,500)/QALY (Colon-Emeric et al., 2003; Honkanen et al., 2006) and another study used $100,000 (€73,000)/QALY (Segui-Gomez et al., 2002) as a threshold. Table 6 also gives an overview of the CEA studies with costs/injury prevented as outcome. The table shows large variation in outcomes, which depends on the injury prevention program analyzed, study population and the methodology used. The compilation of these studies reveals that there is large variation in the cost of preventing injuries. However, most injury prevention programs cost less than €5000 to prevent an injury.

4. Discussion

We systematically reviewed and assessed the quality of 48 economic evaluation studies on injury prevention interventions. Economic evaluation studies published in scientific journals with good accessibility are mainly restricted to fall prevention interventions with few studies covering other causes of injury. The current systematic review shows a wide variety of methodological approaches across studies, including differences in type of economic evaluation, perspective, time horizon, study design, cost categories, effect outcomes, and adjustments for timing and uncertainty used. Most studies have not entirely been performed in accordance with Panel recommendations or BMJ guidelines; e.g. not adopting the societal perspective, not including all relevant

Table 6
Injury prevention interventions and their incremental cost-effectiveness ratio (€).

# (Annex A)	Study population	ICER
CUA studies with cost/QALY outcome		
9	Hip protector – elderly institutionalized residents	€2420/QALY (more effective and less costly)
6	Hip protector – ambulatory nursing facility residents	€11,440–22,290/QALY (depending on cost of hip protector use)
39	Hip protector – nursing home residents	€12,390/QALY
17	Hip protector – community-dwelling geriatric population	Women 75+: €13,840/QALY All other age/sex cohorts: not recommended (=higher costs and lower QALYs)
38	Hip protector – hypothetical cohort men and women 65+	Women: €27,690/QALY Men: not recommended €4370 saved/QALY lost)
18	Community based elderly safety program	€7680/QALY
32	Regulations against cellular telephone while driving	€220,000/QALY
44	Airbag regulation	€17,500–44500/QALY
CEA studies with cost/injury prevented as outcome		
6	Hip protector – ambulatory nursing facility residents	€300/injury prevented
25	Hip protectors – residents of nursing homes	€910/injury prevented
21	Hip protectors – age 50+	€2860/injury prevented
39	Hip protectors – nursing home residents	€7290/injury prevented
33	Exercise program – men and women 80+	€820/injury prevented
15	Fall prevention program – home dwelling women 80+	€2690/injury prevented
35	Exercise program – women age 75+	€970/injury prevented
34	Exercise program – women age 80+	€230/injury prevented
13	Screening for fall risk – inpatients geriatric units	€945/injury prevented
37	Home hazard reduction program – age 65+	€3630/injury prevented
41	Nurse-call system – post-neurosurgery patients	€220/injury prevented
43	Bicycle helmet – cyclists	Age 5–12: €7280/injury prevented
20	Bicycle helmets – age 3–70	€1600/injury prevented
30	Helmet all-terrain vehicles – age 18+	€259/injury prevented
45	Exercises – volleyball players	€440/injury prevented
14	Government regulation – age <10	€380/injury prevented
29	Community education – farm households	€81,990/injury prevented

All costs are converted in Euro's. The outcomes are not corrected for inflation, since many studies did not describe the year of currency.

costs, no incremental CEA. However, numerous studies followed several aspects of these guidelines. Although methodological limitations and differences have to be considered, the results of economic evaluations of injury prevention are encouraging for injury prevention specialists. Most studies conducted so far show very favourable findings regarding the efficiency of the proposed interventions.

As all systematic reviews, our study has some limitations. Reviewing the literature in the field of 'economic evaluations' and also in the field of 'injury prevention' is impeded in both areas by a wide variety of terminology and some relevant publications can therefore be missed. To avoid this to a large extent we used a variety of literature data bases and keywords were matched to database specific indexing terms. Nevertheless, it must be considered that with the data sources that we used, combined with lack of accessibility of full papers in our library systems, relevant studies on traffic and occupational injuries might be missed. For example, there were economic evaluation papers on traffic injuries found by our searches of which no full paper was available (e.g. (Baltes, 1999; Council et al., 2005; Zaloshnja and Miller, 2007)) and for reasons of poor accessibility these papers could not be included. In addition, many economic evaluation studies in the fields of traffic and occupational injuries are published in other data sources than scientific journals (e.g. in reports and books). Some systematic reviews exclude publications in grey literature (e.g. (European Transport Safety Counsel, 2003; Elvik et al., 2009; Miller et al., 2009)). Blackhall stated that the inclusion of unpublished and grey literature in reviews, in particular for injury prevention studies, is essential for minimizing the potential effects of publication bias. Some argue that published studies cannot be assumed to be an accurate representation of the whole evidence base, as studies that show statistically significant, positive results are more likely to be published than those that do not (Blackhall, 2007). In our study this should result in a bias that may be good for our case, since we are reporting then only papers showing favourable ratios for promotion of injury interventions and missed studies in the grey literature providing inefficiency arguments. In our experience, that is not the case, since the grey literature studies also report efficient results (Butry et al., 2007; Miller et al., 2009). In this review we have only focused on articles published in scientific journals. The main reason for this is that we aimed to give a description of the methodological quality of the performed studies instead of giving an advice of how to allocate injury prevention and control resources in such a way as to maximize the returns on investment.

Because of the difficulties in actually gathering all and every paper ever meeting inclusion/exclusion criteria in our or many other searches, we suggest summary statistics on the findings should be treated as the plausible direction, as in treating the identified papers as a (random) sample of all possible papers as opposed to a census (i.e., exhaustive) collection.

Our database search identified many papers that claim the term 'economic evaluation'. Further elucidation showed that in the past 12 years just a tiny fraction (48 studies) performed a proper economic evaluation study within the very broad arena of injury prevention policy which was published in the peer-reviewed literature we could access affordably. The most common area for economic evaluation studies relate to fall prevention in elderly people, which is perhaps unsurprising given the potential role played by a variety of interventions in helping to reduce the risk of hip fractures. This is explainable, since hip fractures have by far the highest share in total costs of injuries in European countries, caused by the highest incidence rate and also the highest mean costs per patient (Polinder et al., 2005). However, there is an urgent need to widen the breadth of injury interventions studied (e.g. child safety, and sport injuries) using rigorous methods for cost-effectiveness to be able to use them for priority setting.

There has been a long-standing emphasis in health economics toward standard reporting of study assumptions and basic cost and health outcomes (Drummond et al., 2005). The reporting quality of the economic evaluation studies was assessed using the checklist for reporting reference-case cost-utility analyses recommended by guidelines developed for economic submissions to the BMJ and

the Panel on Cost-Effectiveness in Health and Medicine, which was published in 1996 (Gold et al., 1996). These quality assessment guidelines were reported and used by Ruger and Emmons (2008). These guidelines were established to improve the quality and consistency of future economic evaluations in health and medicine. Although the assessed studies were published between 1998 and 2009 and numerous studies included certain aspects of the guidelines and provided useful research findings for the injury field, most studies deviated from one or more of the Panel recommendations or BMJ guidelines. This is in common with other areas of health and medicine, especially in the area of (community) prevention interventions (Ramsey, 2000).

First of all, the interpretation and comparability of the reviewed economic evaluation studies is hampered because the perspective of the analysis, the time horizon, data collection methods, or assumptions used in developing models are often not clearly defined. Furthermore, many studies did not adopt the societal perspective, although according to the Panel, employing any perspective other than societal limits the generalizability of the results and weakens the strength of the study findings. Although there were many studies with a comprehensive enclosure of cost components, in several studies not all relevant costs were included, suggesting these research findings are conservative estimates of potential savings. At the opposite, all reviewed CEA and CUA studies clearly reported the primary effect outcome measure. It is generally accepted to discount costs and benefits, although more than half of the studies failed to discount benefits or costs that arise in different years. The lack of a common core of basic methodological choices and the narrow scope of most research questions currently prevents policy makers from the final purpose for which these analyses are useful: deciding how to best prioritize injury prevention interventions. Current differences in the design, reporting, and description of economic evaluations and in model assumptions, data definition and estimation, discount rates and perspectives, limit the ability to make head-to-head comparisons of the most effective and efficient injury prevention programs.

On the basis of this systematic review, it can be concluded that despite a decade of work on this matter, consensus on basic methodological choices in conducting economic evaluations of injury prevention measures has not been reached yet. The quality and comparability of future economic evaluation studies on injury prevention may be largely enhanced by the development of an extensive common core of basic methodological choices. For instance, the use of a societal perspective, common cost categories, standardized measurement of health effects, and consensus on discounting rates facilitates comparison between interventions. Also, more transparency in reporting of the applied methods and data collection should be emphasized, which could be encouraged by developing guidelines with a checklist for economic evaluation submissions by journals. Furthermore, the value of economic evaluation studies for injury prevention measures would increase if the methods were in line with the methodology used for other public health issues. This will enhance that policy-makers base their decisions on objective information in order to maximize the effectiveness of their injury prevention policy in terms of health outcome and efficient spending of resources. Only then economic evaluations can be used for priority setting: comparing with other public health issues and comparing within the domain of injuries. Health economists have aimed at standardizing and generalising economic evaluations to inform health policy debates (Gold et al., 1996; Oostenbrink et al., 2002; Drummond et al., 2005). Therefore, economic evaluation studies for injury prevention interventions should follow guidelines for the standardization of economic analysis such as those suggested by the Panel, amplified with a conceptual framework specific for injury prevention interventions to assist researchers in the injury field in designing and reporting economic evaluations.

To our knowledge, this is the first study that critically examined the methodological quality of published economic evaluation studies in the injury prevention field. Earlier reviews of economic evaluation studies in the injury prevention field had more specific topics.

For instance, reviews have been published of the cost-effectiveness of interventions in reducing the risk of new falls among elderly (Smith and Fordham, 2001; Davis et al., 2010) and cost-effectiveness of municipality based interventions (Gyllensvard, 2010). One of their conclusions is that there are very few economic studies relating to injury prevention programs. The scarcity of economic studies is in line with the conclusions in this study. Miller published a review on cost-outcome analysis in injury prevention and control in the United States (Miller and Levy, 2000) in which he gave a description of cost-outcomes of 84 published and unpublished interventions. However, the quality of these studies was not critically assessed using standard criteria. They conclude that injury prevention interventions often can reduce medical costs and save lives. Another observation of this study was that too few injury causes have been the subject of economic evaluation studies; most interventions studied were those against falls and road traffic injuries.

This review served to map the limitations and difficulties with regard to economic evaluation studies of injury prevention programs. Improving their scope, quality and comparability – which makes these studies more supportive for choosing between alternative interventions – may largely expand the usefulness of economic evaluation studies in the injury prevention field. In combination with established standards, the development and application of detailed harmonization procedures and guidelines allowing for methodological improvements and enhanced comparability of economic evaluation studies in the field of injury prevention is therefore recommended.

5. Statement of contributorship

S. Polinder and E. Belt carried out the search, selected included papers, independently critically appraised the selected papers, developed the evidence tables. S. Polinder wrote the initial draft of the paper. E.F. van Beeck was reviewer for included critically appraised papers, and contributed to the writing of the paper. E.F. van Beeck, M. Segui-Gomez, E. Belt, H. Toet, D. Sethi, and F. Racioppi contributed substantially to the interpretation of study findings and writing the paper.

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Appendix A. Overview of included papers, numbered.

	Title	First author	Year
1	Economic analysis of a community-based falls prevention program	Beard, J.	2006
2	Cost-effectiveness of a patient–sitter program in an acute care hospital: a test of the impact of sitters on the incidence of falls and patient satisfaction	Boswell, D.J.	2001

Appendix A. (*Continued*)

	Title	First author	Year
3	Hospital cost is reduced by motorcycle helmet use	Brandt, M.	2002
4	Safety and economic impacts of photo radar program	Chen, G.	2005
5	Reducing injuries among native Americans: five cost-outcome analyses	Zaloshnja, E.	2003
6	An economic analysis of external hip protector use in ambulatory nursing facility residents	Colon-Emeric, C.S.	2003
7	An Australian experience with tractor rollover protective structure rebate programs: process, impact and outcome evaluation.	Day, L.	2004
8	Economic impact of motorcycle helmets: from impact to discharge	Eastridge, B.J.	2006
9	Cost-effectiveness of preventing hip fractures by hip protectors in elderly institutionalized residents in Germany	Gandjour, A.	2008
10	Determining the cost effectiveness of a smoke alarm give-away program using data from a randomized controlled trial	Ginnelly, L.	2005
11	Medicaid-based child restraint system disbursement and education and the vaccines for children program: comparative cost-effectiveness	Goldstein, J.A.	2008
12	Cost effectiveness analysis of a smoke alarm giveaway programme in Oklahoma City, Oklahoma	Haddix, A.C.	2001
13	Cost-effectiveness analysis of screening for risk of in-hospital falls using physiotherapist clinical judgement	Haines, T.	2009
14	Cost-effectiveness analysis of a proposed public health legislative/educational strategy to reduce tap water scald injuries in children	Han, R.K.	2007
15	Cost-effectiveness in fall prevention for older women	Hektoen, L.F.	2009
16	A cost-benefit analysis of external hip protectors in the nursing home setting	Honkanen, L.A.	2005
17	Can hip protector use cost-effectively prevent fractures in community-dwelling-geriatric populations?	Honkanen, L.A.	2006
18	Non-pharmaceutical prevention of hip fractures – a cost-effectiveness analysis of a community-based elderly safety promotion program in Sweden	Johansson, P.	2008
19	A maternity hospital-based infant car-restraint loan scheme: Public health and economic evaluation of an intervention for the reduction of road traffic injuries	Kedikoglou, S.	2005
20	Age gradient in the cost-effectiveness of bicycle helmets	Kopjar, B.	2000
21	Are hip protectors cost effective?	Kumar, B.A.	2000
22	Cost-benefit analysis of an alcohol ignition interlock for installation in all newly registered vehicles	Lahausse, J.A.	2009
23	A cost-benefit analysis of the community-based injury prevention programme in Motala, Sweden – A WHO safe community	Lindqvist, K.	2001
24	Effectiveness of black spot programs in Western Australia	Meuleners, L.B.	2008
25	Increased use of hip protectors in nursing homes: Economic Analysis of a Cluster Randomized, Controlled Trial	Meyer, G.	2005
26	Cost savings from a sustained compulsory breath testing and media campaign in New Zealand	Miller, T.R.	2004
27	Cost-outcome analysis of booster seats for auto occupants aged 4–7 years	Miller, T.R.	2006
28	Effectiveness and benefit-cost of peer-based workplace substance abuse prevention coupled with random testing	Miller, T.R.	2007
29	Cost-effectiveness of a ROPS retrofit education campaign	Myers, M.L.	2003
30	Cost-effectiveness of wearing head protection on all-terrain vehicles	Myers, M.L.	2009
31	Prevention effectiveness of rollover protective structure – Part III: Economic analysis	Pana-Cryan, R.	2000
32	Cost-effectiveness of regulations against using a cellular telephone while driving	Redelmeier, D.A.	1999
33	Effectiveness and economic evaluation of a nurse delivered home exercise programme to prevent falls. 2: Controlled trial in multiple centres	Robertson, M.C.	2001
34	Economic evaluation of a community based exercise programme to prevent falls	Robertson, M.C.	2008
35	Effectiveness and economic evaluation of a nurse delivered home exercise programme to prevent falls. 1: Randomized controlled trial	Robertson, M.C.	2001
36	A retrospective benefit-cost analysis of the 1997 stair-fall requirements for baby walkers	Rodgers, G.B.	2008
37	The cost effectiveness of a home hazard reduction program to reduce falls among older persons	Salked, G.	2000
38	Cost and effectiveness of hip protectors among the elderly	Segui-Gomez, M.	2002
39	Cost-effectiveness of hip protectors in the prevention of osteoporoses related hip fractures in elderly nursing home residents	Singh, S.	2004
40	The cost-effectiveness of home assessment and modification to reduce falls in the elderly	Smith, R.D.	1998
41	Cost effectiveness of a medical vigilance system to reduce patient falls	Spetz, J.	2007
42	A benefit-cost analysis of the Harlem hospital injury prevention program	Spicer, R.S.	2004
43	New Zealand bicycle helmet law – do the costs outweigh the benefits?	Taylor, M.	2002
44	Validating benefit and cost estimates; the case of airbag regulation	Thompson, K.M.	2002
45	An economic evaluation of a proprioceptive balance board training programme for the prevention of ankle sprains in volleyball	Verhagen, E.A.L.M.	2005
46	A cost-benefit analysis of risk reduction strategies targeted at older drivers	Viamonte, S.M.	2006
47	Is it cost-effective to require recreational ice hockey players to wear face protection?	Woods, S.E.	2008
48	An economic evaluation of energy-absorbing flooring to prevent hip fractures	Zacker, C.	1998

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