Speed enforcement detection devices for preventing road traffic injuries (Review)

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TABLE OF CONTENTS

[Intervention Review]

Speed enforcement detection devices for preventing road traffic injuries

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ABSTRACT

Background

It is estimated that by 2020, road traffic crashes will have moved from ninth to third in the world ranking of burden of disease, as measured in disability adjusted life years. The identification of effective strategies for the prevention of road traffic injuries is of global public health importance. Measures aimed at reducing traffic speed are considered essential to preventing road injuries; the use of speed enforcement detection devices (including speed cameras and radar and laser devices) is one such measure.

Objectives

To assess whether the use of speed enforcement detection devices (SEDs) reduces the incidence of speeding, road traffic crashes, injuries and deaths.

Search strategy

We searched the Cochrane Injuries Group's Specialised Register, the Cochrane Central Register of Controlled Trials, MEDLINE, EMBASE, other databases and reference lists of articles. We also contacted experts in the field. The searches were conducted during May to November 2004.

Selection criteria

Randomised controlled trials and controlled before-after studies that assessed the impact of speed enforcement detection devices on speeding, road crashes, injuries and deaths were eligible for inclusion.

Data collection and analysis

We independently screened search results, assessed studies for inclusion, extracted data and assessed methodological quality. Due to variability between and within included studies, a pooled analysis was not appropriate.

Main results

Twenty-six studies met the inclusion criteria. All but one study reported an absolute reduction in pre/post average speeds. A pre/post reduction in the proportion of speeding vehicles ranged across studies from 5% to 70% depending on the speed threshold set. Pre/post reductions of 50% to 65% were reported in the proportion of speeding vehicles travelling >15 km/h over the speed limit. Compared with controls, the relative improvement was from 1% to 15% for average speed and from 14% to 65% for percent speeding.

All studies reporting crash outcomes reported an absolute pre/post reduction in all crashes and injury related crashes. In the vicinity of camera sites these pre/post reductions ranged from 14% to 72% for all crashes, 8% to 46% for injury crashes, and 40% to 45% for crashes resulting in fatalities or serious injuries. Compared with controls, the relative improvement in pre/post crash numbers resulting in any type of injury ranged from 5% to 36%.

Authors' conclusions

Despite the methodological limitations of the studies reviewed, the consistency of reported positive reductions in speed and crash outcomes across all studies suggest that SEDs are a promising intervention for reducing the number of road traffic injuries and deaths. More studies of a scientifically rigorous nature are necessary to provide a stronger evidence base that these interventions are worthwhile.

PLAIN LANGUAGE SUMMARY

Do speed enforcement detection devices (including speed cameras and radar and laser devices) reduce death and injury from road traffic crashes?

Road traffic crashes are a major cause of death and disability. The speed at which a vehicle travels is an important determinant of injury; the faster the vehicle is travelling, the greater the energy inflicted on the occupants during a crash and the greater the injury.

Excessive speed (driving faster than the posted limit or too fast for the prevailing conditions) has been found to contribute to a substantial number of crashes. It is predicted that, if the number of speeding drivers is reduced, both the likelihood and severity of a crash will be lowered. Therefore, interventions aimed at reducing traffic speed are considered essential to preventing road injuries. The implementation of SEDs (speed enforcement detection devices; including speed cameras and radar and laser devices) is one such measure.

To evaluate the effectiveness of SEDs, the authors examined all eligible studies comparing areas before and after introduction of SEDs and their effect on road traffic crashes, injuries and speeding to areas with no SEDs.

The authors found 26 studies, of which 21 measured the effect on crashes, all of which found a lower number of crashes in the SEDs area. In the vicinity of SED sites the reductions ranged from 14% to 72% for all crashes, 8% to 46% for injury crashes, and 40% to 45% for crashes resulting in fatalities or serious injuries. Effects over wider areas showed a crash reduction ranging from 9% to 35%, 7% to 30% for all injury crashes and 13% to 58% for crashes resulting in fatalities or serious injuries. The studies of longer duration showed that these positive trends were either maintained or improved with time.

Despite the quality of the included studies being judged to be weak, the consistency of reported positive reductions in speed and crash outcomes across all studies suggest that SEDs are a promising intervention for reducing the number of road traffic injuries and deaths. However, higher quality studies using well designed controlled trials are needed to confirm this finding. As none of the studies were conducted in low-income countries, research in such settings is required. There is a need for consistency in methods, such as standards for the collection and reporting of speed and crash data, so that studies can be compared more easily. Studies should also continue careful data collection for lengthy follow-up periods after the installation of SEDs.

BACKGROUND

The pandemic of road traffic deaths and injuries continues unabated. Each year almost 1.2 million people die and between 20 and 50 million people are injured or disabled worldwide as a result of road traffic crashes (Peden 2004). For people under 44 years, road traffic crashes are a leading cause of death and disablement second only to HIV and AIDS (Krug 2002). The continuing advance of motorisation in many developing countries is likely to further exacerbate the problem. It is estimated that by 2020 road traffic crashes will have moved from ninth to third in the world ranking of burden of disease, as measured in disability adjusted life years (Murray 1997). Thus, the identification of effective strategies for the prevention of road traffic injuries is of public health importance globally.

The relationship between speeding and crash rate, and speeding and injury rate has been examined in many studies and reviewed by the US Transportation Research Board (US TRB 1998). The relationship between speeding and the likelihood of crashing should be logical; increasing speed increases the reaction distance (the distance travelled while the driver is reacting to a situation) and the braking distance. In reality, the relationship between speeding and crash rate is not simple, but it is consistent across studies. In two-car crashes, the greater the deviation in speed from the average, the higher the rate of crashes. This relationship is thought to be due to increased interactions between vehicles when travelling at different speeds. In single-vehicle accidents, the higher the speed, the greater the risk of crashing. The relationship between speeding and injury rate is straightforward; the faster the vehicle is travelling, the greater the energy absorbed by the occupants during the rapid change in velocity that occurs during a crash.

Speed limits on roads are used to regulate traffic speed and thus promote road safety by establishing an upper limit on speed, and by reducing the variance ('dispersion') of the speed of vehicles. As injury severity increases non-linearly in relationship to speed, curbing 'top-end' speeders should also reduce the number of deaths and severe injuries in those crashes that do occur. Speed limits are usually assigned by category, type, and design of the road (Chin 1999). Many countries provide some type of enforcement to ensure that drivers obey the posted speed limits.

In Australia, during 2002, there were 1715 fatal crashes, of which 562 were identified as involving excessive speed (defined as driving faster than the posted limit or too fast for the prevailing conditions), using data obtained from the Australian Transport Safety Bureau (ATSB 2003). It is predicted that, if the number of drivers who are speeding is reduced, both the likelihood and severity of a crash will be lowered (Pilkington 2002). The enforcement of speed limits must be sufficient to ensure that drivers believe that if they speed, they will be caught. Police cannot be present on all roads at all times and therefore, in many countries, there is increasing use of automatic speed enforcement, using detection devices (speed cameras) that may be manned or unmanned, mobile or fixed as well as overt or covert.

Automatic speed enforcement has the capability of being a substantial net revenue-raising activity. This blurs the line for the public as to whether governments use the device for safety or for fiscal reasons, and may harden attitudes towards their use. Some people view the introduction of speed cameras as a violation of their civil liberties. Legal issues, such as whether the owner or the driver of a vehicle is responsible for the speeding violation, also arise. The arguments for and against speed cameras have been highlighted in British Columbia, Canada. The trial by Chen 2000 concluded that the introduction of cameras had reduced speeding, with a corresponding decrease in crashes, injuries and fatalities. Nevertheless, in June 2001, the speed camera program was discarded by the incoming government. Most countries however that have introduced speed cameras have tended to expand their use over time. This is particularly noticeable within the United Kingdom and Australia.

The aim of this systematic review was to determine whether the use of speed detection devices reduces the incidence of speeding, crashes, injuries and deaths. A secondary consideration was to examine the relative effectiveness of covert versus overt cameras, halo effects and mean and actual speeds. Little empirical evidence currently exists for the relative effectiveness of covert detection devices versus devices that can be seen. It is thought that while overt cameras should reduce speeds at road crash 'black spots' (also called 'hotspots'), covert cameras should reduce speeds over a wider area (Keall 2001). Likewise, other questions that need to be answered centre upon the so-called 'halo' effects. For example, the length of time an effect of enforcement is present after detection devices have been removed is known as the time-halo. The distance-halo is the distance from the point of speed enforcement that the decrease in speed continues. Regarding speed, speed cameras may lower the mean (relative) speed on the road (for example, the mean speed could fall from 110 km/h to 107 km/h in a 100 km/h zone), or they may lower the top speeds (absolute) on the road (for example, the top speed may be 150 km/h pre camera and 130 km/h post camera in a 100 km/h zone). This review considered both types of speed reduction.

In order to ensure the highest possible level of evidence available, studies selected for this review included only before-after trials and interrupted time series studies with control or comparison areas. This is in contrast to the only other systematic review that exists on speed cameras, which included both controlled and uncontrolled before-after studies (Pilkington 2005).

OBJECTIVES

The objective of this systematic review was to investigate whether speed enforcement detection devices lower:

- the percentage of speeding drivers on the road;
- the absolute speeds above the speed limit;
- the rate and severity of injurious crashes on the road.

METHODS

Criteria for considering studies for this review

Types of studies

Studies were included if they involved any of the following research designs:

- randomised controlled trials (RCTs) (including clustered RCTs and quasi-RCTs);
- controlled before-after studies (CBAs);
- interrupted time series studies (ITSs).

The definition of CBA and ITS designs are based on that used by the Cochrane Effective Practice and Organisation of Care group (EPOC) as follows:

- CBA: A design where there is contemporaneous data collection before and after the intervention and an appropriate control site or activity;
- ITS: A design where there is a clearly defined point in time when the intervention occurred and at least three data points before and three after the intervention.

The inclusion of trials was not restricted by language or publication status.

Types of participants

Drivers of all motorised vehicles.

Types of interventions

All methods available for speed enforcement (including speed cameras, and radar and laser devices) that were: attended or unattended; mobile or fixed and overt or covert were considered. As the effect of co-intervention is difficult to exclude in studies such as these, studies that did not have the aforementioned speed enforcement devices as the major intervention focus were not eligible for inclusion.

Types of outcome measures

- Percentage of speeding drivers above the speed limit or designated speed threshold, and their average speeds in areas with and without cameras: to investigate the overall effect of the enforcement.
- The absolute pre/post change in speed or the percentage pre/post change in speed in areas with and without cameras.
- Duration of speed reduction (i.e. time and distance halos): to investigate the local and widespread effects of the enforcement.
- Crash and injury outcomes: All road user deaths and injuries and all road traffic crashes. Our definition of 'road users' included drivers and their passengers, cyclists and pedestrians.

Search methods for identification of studies

Electronic searches

We searched the following transportation, educational and medical electronic databases:

- Cochrane Injuries Group Specialised Register;
- The Cochrane Library (CDSR and CENTRAL);
- MEDLINE (via WebSPIRS 1962 to January 2006);
- EMBASE (via WebSPIRS 1995 to January 2006);
- TRANSPORT (includes the Transport Research Information Services - TRIS), the International Road Research Documentation - IRRD) and the European Conference of Ministers of Transport (TRANSDOC) databases) (1968 to November 2004);
- Web of Science (Science (and Social Science) Citation Index (1981 to May 2004);
- PsycINFO (1980 to August 2004);
- CINAHL (1982 to August 2004);
- EconLit;
- WHO database;
- Sociological Abstracts;
- Dissertation Abstracts;
- Index to Theses.

The search strategy can be found in Appendix 1.
The librarians at the Institute for Road Safety Research (SWOV) in the Netherlands also ran a search for us (in Dutch) in order to capture any relevant studies from the Nordic countries not published in English.

Searching other resources

Handsearches

We handsearched the journals Accident Analysis and Prevention (1974 to 2004) and Injury Prevention (1995 to 2004).

Internet searches

We searched the websites of a number of road safety organisations, a full list is presented in Appendix 2.
We set up a daily Google Alert (15/04/2004 to ongoing) The following search words were found to be the best combinations, accounting for the greatest number of relevant 'hits':

- speed camera study
- automatic enforcement speed* study
- speed camera before after study
- speed camera before after control*
- safety speed camera trial study
- speed roads control* before and after study

- speed* camera* injury accident crash* speed camera road study
- speed camera halo effect, safety speed camera enforce*
- speed* camera* collision * crash* trial * speed* camera* injury*
- before after, study* speed* camera* police, safety camera enforce* control

The settings for Google Alert allowed these search words to be further utilised by restricting the search to different timeframes and/or countries. Certain search words used for other databases such as photo radar and laser were quickly abandoned in Google due to the large amount of advertising materials they generated. British Medical Journal (BMJ) customised alerts (weekly) was also set up using the search terms randomised controlled trials, controlled trial, before and after studies, speed or safety camera, road crashes, road injury and their related thesaurus terms.

Unpublished studies

In an effort to identify unpublished studies we contact experts in the field and searched national registers on ongoing trials.

Snowballing

We attempted to identify further potential published or unpublished studies by checking references of relevant articles, reviews and books, contacting authors of relevant papers, contacting international and national road safety organisations as well as voluntary agencies with an interest in road safety. We also perused daily newspaper and news reports (for example, BBC news online (daily)) for references to relevant articles.

Conference proceedings

We searched the following conference proceedings:

- Road Safety Research, Policing and Education Conference - www.rsconference.com;
- ICTCT International Co-operation on Theories and Concepts in Traffic Safety www.ictct.org/workshops/;
- RoSPA - Royal Society for the Prevention of Accidents http://www.rospa;
- Travelsafe Committee - www.parliament.qld.gov.au/committees/travel.htm;
- 6th World Conference Injury Prevention and Control www.inspq.qc.ca/pdf/publications/InjuryPreventionControl2002.asp;
- Road Traffic Injuries and Health Equity Conference 2002 Massachusetts www.hsph.harvard.edu/traffic/papers.html;
- Road Safety on Three Continents Conference South Africa 2000 www.vti.se/pdf/reports/K15A.pdf;
- ARRB - Australian Research Board Conference 17th www.arrb.org.au;
- 7th World Conference on Injury Prevention and Safety Promotion Vienna 2004.

Data collection and analysis

There were five stages of the review process.

Stage 1: Identification of studies for inclusion

One author (CW) initiated the search for trials. A second author (CMW) continued the search, finding titles, abstracts and full articles, and then short-listed studies.

Stage 2: Selection of studies for inclusion

Relevant studies selected from the process in stage one were independently assessed against the inclusion criteria by two authors (CMW, CW). Investigators were contacted where possible for any additional information regarding trials that potentially fulfilled the inclusion criteria.

Stage 3: Data Extraction

Data were independently extracted from the included studies by the three authors using a standardised form, which was piloted before use. Data extracted were extracted on the following:

- details of the study design;
- study participants;
- setting of the study;
- types of interventions used;
- characteristics of intervention and control sites;
- measures of exposure and outcomes;
- treatment of confounders;
- results.

Differences or disagreements found were resolved by detailed discussion with all authors (CMW, CW, JH, NB). Where necessary, additional information was sought from study authors.

Stage 4: Quality assessment

The assessment of the quality of non-randomised trials is problematic. Controlled before-after studies (CBAs) and interrupted time series studies (ITSs) are recognised to be methodologically weaker than randomised controlled trials, and few quality assessment instruments exist for non-randomised studies. Having perused the literature for validated tools, and discussed the issue at length with experts in the field, it was decided to use a quality assessment process based on the Data Collection Checklist described by the Cochrane Effective Practice and Organisation of Care Review Group (EPOC).

Quality assessment was performed independently by two authors (CMW, CW). The process was based on four of the seven criteria used for the quality assessment for CBA designs, and the two additional criteria for ITS designs, used by EPOC. The criteria chosen were those that are relevant to community trial designs and specifically determine the appropriateness of baseline measurements, characteristics of the control site, protection against contamination between sites, and reliability of the outcome measures. ITS studies were also scrutinised against the EPOC quality criteria of a clearly defined point in time when the intervention occurred, and at least three data collection points before and after the intervention. All disagreements were resolved by consensus.

Stage 5: Syntheses of results

In addition to the description of outcomes in the characteristics of included studies table, the results from studies were also presented in the additional tables section of this review. Two tables (Table 1; Table 2) were used to show results from the CBAs, with one table depicting speed outcomes and the other crash outcomes. Studies that reported both speed and crash outcomes were highlighted with an asterisk. Table 3 shows results from the ITS studies.

Table 1. Summary of Speed Outcomes - CBAs

Study ID	Outcomes	RSR	PSRRR	Ratios based on
	* denotes studies reporting both speed and crash outcomes.	Relative speed ratio (RSR)	% Speeding relative rates ratio (PSRRR)	
AU NSW 1	About 70% reduction in speeding vehicles when police present. A time halo effect lasted at least 2 days.	Not reported.	0.78 (CI incalculable).	3 post occasions. 2 times of day. Speed limit (SL) = 60km/hr % vehicles speeding
NO Oslo	Reduction in average speeds by 0.9 to 4.8 km/h for all times of day. 10% reduction in proportion of speeding drivers. A time halo effect of up to 8 weeks was shown.	Graphs only. No control data reported.	Graphs only. No control data reported.	2 SLs 3 periods each day Weekly Time Series (2 pre, 6 during, 8 after)
*CA British Columbia	Proportion of speeding drivers reduced at experimental sites, from 66% to 35%, compared to before.	Graphs only.	0.53 (CI incalculable).	Warning versus post-intervention Specific months reported for Experiment Mean of months within

Table 1. Summary of Speed Outcomes - CBAs *(Continued)*

				phase for Control % vehicles speeding
*CA Vancouver	2.8 km/h reduction in mean speed at monitoring site 2km from treatment site.	Graphs for experimental site are unclear.	Not reported.	8 locations over 3 regions Monthly time series
US Washington DC	A significant 14% reduction in mean speeds compared to control sites. The proportion of vehicles exceeding the speed limit by more than 10mph decreased by 82%.	0.852 (95% CI 0.847 to 0.857)	0.35 (95% CI 0.30 to 0.40)	7 experimental sites (SL: 25 - 30mph) 8 control sites (SL: 25 - 35 mph) Weighted mean and variance Sp: Formula for variance of ratios
AU QLD 2	Reduction in speed and narrowing of speed distribution for 60km/h, 70km/h and 100km/h zones at experimental sites.	Graphs only.	Graphs only.	3 SLs (60, 70 and 100km/hr)
*AU Tasmania	Significant average 3.6 km/h decrease in mean speed compared to before. No time halo effect seen.	0.96 (95% CI 0.88 to 1.05).	Not reported.	Means of mean speeds recorded on different days within the pre and post periods Pooled variance of 3 post-period means Formula for variance of ratios
*DE Germany	Reductions in median speed by 40 km/h and 28km/h in left and middle car lanes and 23km/h in truck lane by the end of 10 years of enforcement. Also reductions in 85th percentile speeds of 42 and 37km/h in car lanes and 39km/h in truck lane.	Medians graphed.	Medians graphed.	Cumulative speed distributions for pre-post reported
*AU NSW 2	Overall mean speed reduction of about 2-3km/h seen at both experimental and control sites. Distance halo of	0.99 (CI incalculable).	Not reported.	10 expt sites. 5 control sites. Cars and trucks. 2 speed limits. 2 occasions during intervention.

Table 1. Summary of Speed Outcomes - CBAs *(Continued)*

	up to 14km downstream was seen. Time halo for at least the day after enforcement.			Unweighted means of two interventions.
CA Toronto	A time halo effect lasted for 3 days following a single application of enforcement. With 5 days of consecutive enforcement a time halo of at least 6 days was noted. At the site of speed limit enforcement the average speed was reduced to around the posted speed limit. This reduction in average speed was seen to decay exponentially with distance downstream.	Experimental data tabled. Control data graphed.	Not reported.	Experimental 3, enforcement site only. 5 consecutive enforcement days. Several pre and post occasions
*FI Finland	On 80 km/h sections an 8% reduction of speeding vehicles seen on experimental sites compared to control sites in year one, with a further 2% decrease in year 2. On 100 km/h stretches a 5% reduction in number of speeders was seen in year one, with a further 2% reduction in year 2. Distance halo of 3 km upstream and 2 km downstream.	Only pre-post differences reported.	0.66 (CI incalculable).	Annual data for two years post. Two speed limits. Geometric means. Post=during
AU South Australia	Sharp reduction of 5 km/h in median speed on experimental roads after program launch, which was sustained throughout the 15 month trial period. No further reduction observed despite intensified enforcement.	Graphs only.	Graphs only.	3 interventions, so results based on pre and post last intervention
*HK Hong Kong	65% reduction in speeding vehicles in excess of 15km/h or more over the			

Table 1. Summary of Speed Outcomes - CBAs *(Continued)*

	speed limit.			
*DK Denmark	During pilot program an overall 2.4 km/h reduction in mean speed with only small differences between the 3 cities. A 10.4% reduction in % of drivers exceeding speed limit and a 4.5% reduction in those exceeding the speed limit by 10km. A 22% reduction in injurious crashes in first year and 20% in second year post intervention compared to before.	Not reported.	Not reported.	Enforcement and control and sites not graphed separately.
NZ Nationwide	2.3 km/h reduction in mean speeds (P=0.05) at speed camera sites on open roads compared to rest of country in the first year.	0.98 (CI incalculable). Also see ITS table.	0.86 (CI incalculable)	June 97 not included in RSR because of publicity effect. Weighted mean speed of post data used. No SDs reported. Ticket rate used as proxy for % speeding.
*NL Netherlands	Aggregation of data from the 4 roads (compared to phase 0) showed a reduction in average speed of 3km/h in phase 1 and 5km/h in phase 2, a reduction in 85 percentile speed of 3km/h in phase 1 and 8 km/h in phase 2. A reduction in proportion of speeders from 38.2% to 28% in phase 1 and from 38.2% in phase 1 to 11.4% in phase 2.	0.936 (95% CI 0.931 to 0.941)	0.43 (95%CI 0.41 to 0.46)	Aggregate vehicle data for 4 provinces, 2 roads per province as reported in English version. Weighted mean speed and SD across two intervention phases. Aggregated PS for two intervention phases.

Table 2. Summary of Crash Outcomes - CBAs

Study ID	Outcomes	Crashes	Injuries	Fatalities	Results based on

Table 2. **Summary of Crash Outcomes - CBAs** *(Continued)*

	* denotes studies reporting both speed and crash outcomes	Relative crashes ratio (RCR) with (95% CI) or % crashes relative risk ratio (PCRRR) with (95% CI)	Relative crashes ratio (RCR) with (95% CI) or % crashes relative risk ratio (PCRRR) with (95% CI)	Relative crashes ratio (RCR) with (95% CI) or % crashes relative risk ratio (PCRRR) with (95% CI)	
GB South Wales	Reduction of 50% in personal injury accidents (0-500m route)	Not reported	Neither reported nor calculable.	Not reported	RCR based on control (post, pre) and experimental (pre) only.
NO Nationwide	A significant 20% reduction in injury crashes equating to about 62 injury crashes per year on all 64 road sections combined	Not reported	RCR = 0.79 (95%CI 0.72 to 0.88)	Not reported	5 SLs. 4 traffic scenarios. RCR.
*CA British Columbia	A 25% reduction in expected crash rate, 11% reduction in injury crashes and a 17% reduction in daytime crash fatalities	Graph estimates only. Time series -see ITS table	Graph estimates only. Time series - see ITS table.	Graph estimates only. Time series -see ITS table	
*CA Vancouver	A reduction of 16% (+/- 7%) in expected crashes along study corridor. A 2.8km/h reduction in mean speed at monitoring site.	RCR = 0.95 (95%CI 0.74-1.22)	Not reported	Not reported	Aggregated counts over 8 locations in 3 regions.
AU QLD 2	Estimated reduction in fatal crashes in areas within 2km of camera sites. Corresponding 31% (1100), 39% (2200), 19% (500) and 21% (1600) reductions were estimated for hospitalisation, medically	Not reported	Graphs only	Graphs only	3 SLs (60, 70 and 100km/hr). Fatal and hospitalization crashes are combined for the "fatal" result.

Table 2. Summary of Crash Outcomes - CBAs *(Continued)*

	treated, other injury and non-injury crashes respectively.				
*HK Hong Kong	23% reduction in number of injury crashes. 66% reduction in fatal crashes	RCR = 0.74 (95%CI 0.54 to 1.02)	RCR = 0.86 (95%CI 0.42 to 1.76)	RCR = 0.33 (0.01 - 4.60)	Exact CI are calculated for fatal crashes.
*AU Tasmania	A significant 58% reduction in serious or fatal injury crashes.	RCR = 0.88 (95%CI 0.75 to 1.02)	RCR = 0.78 (95%CI 0.64 to 0.93)	RCR = 0.72 (0.36 - 1.08)	Based on means per year for pre and for post period. Formula for variance of ratios.
AU QLD 1	A significant 11% reduction in total crashes outside of city. Estimated 31% reduction in fatal crashes	Not reported	Not reported	Not reported	% differences estimated from model.
*DE Germany	Personal injury crash frequency reduced by a ratio of 1:1.	Not reported for control pre intervention	PCRRR = 0.44 (CI incalculable)	Not reported for control	1 year post introduction of radar (1973) cf 2 years pre SL, but post addition of 3rd lane (1970, 1971). RCR - data not available for control arm.
*AU NSW 2	23% crash reduction during the day and a 21% reduction at other times.	RCR = 0.78 (95%CI 0.59 - 1.05)	RCR = 0.81 (95%CI 0.53 to 1.24)	RCR = 0.00 (0.00 - 0.35)	Formula for fatalities based on exact methods. Aggregate of monthly counts.
* FI Finland	A non-significant 19% reduction in crashes (not defined).	Not reported	RCR = 0.81 (95%CI 0.48 to 1.35)	Not reported	Aggregate counts of 24 months pre, 21 months post. Two speed limits. Post = during. SE is a biased conservative estimate.
DK Denmark	During pilot program an overall 2.4 km/ h reduction in mean speed with only	Not reported	Not reported	Not reported	Enforcement and control data is not reported separately.

Table 2. Summary of Crash Outcomes - CBAs (*Continued*)

	small differences between the 3 cities. A 10.4% reduction in % of drivers exceeding speed limit and a 4.5% reduction in those exceeding the speed limit by 10km/h. A 22% reduction in injurious crashes in first year and 20% in second year post intervention compared to before. During pilot program an overall 2.4 km/ h reduction in mean speed with only small differences between the 3 cities. A 10.4% reduction in % of drivers exceeding speed limit and a 4.5% reduction in those exceeding the speed limit by 10km. A 22% reduction in injurious crashes in first year and 20% in second year post intervention compared to before.				
GB West London	A significant 56% reduction in fatal crashes relative to controls and a 12% reduction for all crashes and 25% for serious crashes.	incalculable	incalculable	Incalculable	Control data not provided. % change relative to control is not defined in text.
*NL Netherlands	A reduction of 35% in the total number of crashes for phase 1 and 2 compared to the control roads	RCR = 0.64 (95%CI 0.44 to 0.91)	RCR = 0.66 (95%CI 0.26 to 1.61)	Insufficient data	Aggregate crash data for provinces, 2 roads per province as reported in En-

Table 2. Summary of Crash Outcomes - CBAs *(Continued)*

	and the same period 3 years previously				glish version (Overijssel excluded). Aggregates over 3 pre periods. Exact confidence limits of Common log odds ratio for Post/Pre.
NL Netherlands	Phase 3 - conducted in 1994 on one road in one province Noord-Brabant found the reduction in crashes found in 1991 had been maintained.	RCR = 0.64 (95%CI 0.45 to 0.92)	RCR = 0.79 (95%CI 0.31 to 2.04)	Insufficient data	Aggregates over 3 pre and 3 post periods Aggregates for two control sites.
NZ Christchurch	Measures were average speeds and all crashes and serious injury crashes. The average difference between the 85th percentile and mean for the 4 years before and 4 years after was only 0.8km/h. Reduction of 9.17% in crashes and 32.4% in serious injury compared to New Zealand overall	RCR = 0.91 (95%CI 0.80 to 1.03)	RCR = 0.69 (95%CI 0.48 to 1.00)	Not reported	Injuries = Serious + fatal

Table 3. Study Outcomes - ITSs

Study ID	Results	Outcome measure	Method used	Outcome (95% CI)	Based on
AU VIC 1 (Phase one-Statewide)	Phase 3, 4 and 5 of this 5-phase study did not have before-after data, hence only phase 1 and 2 tabled. Phase 1 - General effects - effect of speed	Outcome = % vehicles speeding over threshold Measure = % vehicles speeding over threshold on three monthly occasions	Graph of monthly data from June 1990 to January 1991	a) -11.3% b) -15.4% c) -8.0%	a) July 1990 b) May 1991 (increase in speed camera use begins) c) October 1991

Table 3. Study Outcomes - ITSs (*Continued*)

	camera program on crash rate and severity covering first twelve month post intervention period.				
Statewide		Outcome = crashes (fatal, serious and minor) Measure = Estimated difference in the percentage change in crashes between experimental and control areas	ARIMA and multiple regression, using multiplicative models and natural logs	a) -9.7% (-19.1% to +0.8%) b) -22.2% (-31.3% to -11.8%) c) -17.9%(-27.9% to -6.6%) d) -15.6%(-31.5% to +4.0%)	Multiple regression a) Low level trialing period b) Intervention period c) Enforcement - no cameras in control areas d) Enforcement - cameras in control areas
Metropolitan		Outcome = % vehicles speeding over threshold Measure = % vehicles speeding over threshold on three monthly occasions	Graph of monthly data from June 1990 to January 1991	a) - 15.8% b) - 8.0%	a) May 1991 (increase in speed camera use begins) b) October 1991
Metropolitan		Outcome = crashes (fatal, serious and minor) Measure = Difference in the estimated percentage change in crashes between experimental and control areas	ARIMA and multiple regression, using multiplicative models and natural logs	a) -6.7% (-17.7% to +5.9%) b) -20.2% (-31.1% to -7.6%) c) -12.7% (-25.4% to +2.1%) d) -3.3% (-24.0% to +23.1%)	Multiple regression a) Low level trialing period b) Intervention period c) Enforcement - no cameras in control areas
AU Vic 1 (Phase 2)	Phase 2 - Impact of program mechanisms i.e. number of traffic infringement notices (tin's) hours of speedcam operations, amount of paid TV publicity, demerit points in relation to injury crash incidence and severity during low				

Table 3. Study Outcomes - ITSs *(Continued)*

	alcohol times of the week across the first 2 year post intervention period				
Metropolitan		Outcome = crashes (fatal, serious and minor) Measure = Log (crashes)	Multiple regression, using multiplicative models and natural logs	a) -0.0065 (-0.0101 to -0.0029) b) -0.0043 (-0.0119 to 0.0034) c) -0.0077 (-0.0128 to -0.0026)	a) Log (TINs issued) b) Log (Speed camera hours) c) Log (All publicity)
Metropolitan		Outcome = crashes (fatal, serious and minor) Measure = Log (ratio of fatal & serious to minor, crash numbers)	Logistic (multiple) regression, using multiplicative models and natural logs	a) -0.0183 (-0.0284 to -0.0082) b) -0.0371 (-0.0572 to -0.0169) c) -0.0019 (-0.0189 to 0.0150)	a) Log (TINs issued) b) Log (Speed camera hours) c) Log (All publicity)
CA British Columbia	Proportion of speeding vehicles in May 1996 (before) at photo radar sites was 66%. By July 1997(after) it was about 35%. At control sites speeding vehicles in Sept 1995 was about 73%, in Nov 1996 it was about 61%. About 25% reduction in crashes to that expected. A significant 11% reduction in number of victims with an average decrease of 139 daytime traffic crashes requiring an ambulance. A 17% reduction in daytime crash fatalities	Outcome = mean speed Measure = estimated difference in mean speed post intervention	Cross-sectional time-series analysis	-2.4km/hr (-3.23 to -1.52)	a) 19 sites b) 15 monthly mean speeds c) Intervention after post-warning phase
		Outcome = crashes Measure = estimated difference in the number of	ARIMA	b) -54 (-113.0 to 5.7) c) -151 (-202.1 to -101.8)	a) Speed related daytime crashes- principally property and minor injuries

Table 3. Study Outcomes - ITSs *(Continued)*

		crashes per month post intervention			b) Warning letters intervention c) Violation ticket intervention
		Outcome = victims Measure = estimated difference in the number of victims per month post intervention	ARIMA	b) -31 (-119.1 to 57.1) c) -140 (-206.9 to -72.2)	a) Daytime victims carried by ambulance b) Warning letters intervention c) Violation ticket intervention
GB Cambridge	A 45.74% reduction in weighted injury crashes within 250 metres from camera sites (total monthly before count of 23.4 compared to total monthly after count of 12.7) with lesser but still significant de- creases observed in the wider surrounding areas, such as, a 20.86% reduction inside a 2000 metre radius from the camera.	Outcome = Crashes Measure = Percentage change in crash estimates	Manual adjustment for time series effects and regression to mean	-34.9% (CI incalculable)	Average over 4 catchment areas Average of pre and post estimates over sites All injury crashes
GB Nationwide	Reduction in long-term average speed of around 8% for fixed cameras sites in rural areas and a 15% reduction for fixed cameras sites in urban areas. About 40% fewer KSI's and 33% fewer PIC's at camera sites. A 40% reduction in fatalities (over 100 fewer deaths) A reduction of 23% in PIC's and 35% in KSI's for	Outcome = speed, Measure = percentage change in mean speed	Monthly averages	-7% (CI not reported)	Weighted mean speed over sites

Table 3. Study Outcomes - ITSs *(Continued)*

	pedestrians.				
		Outcome = % exceeding speed limit Measure = Percentage change in mean percent	Monthly averages	-31.6% (CI not calculable)	Weighted mean speed over sites
		Outcome = Crashes - Killed and serious injuries (KSIs) Measure = Estimated percentage change in crashes	Statistical modeling using Poisson/Log-linear analysis	-39.9% (-42.42% to -41.60%)	Counts on a date for a site
		Outcome = Crashes (personal injury crashes PICs) Measure = Estimated percentage change in crashes	Statistical modeling using Poisson/Log-linear analysis	-32.6% (-36.18% to -28.74%)	Counts on a date for a site
		Outcome = Fatality crashes Measure = Percentage change in mean fatality crashes	Mean count per annum	-40% (CI not reported)	Annual counts, aggregated over sites
NZ - Nationwide	2.3km/h reduction in mean speeds (P= 0.05) at speed camera sites on open roads compared to rest of the country in the first year. A net reduction of 11% in crashes and 19% in injuries on open roads across the region was found, associated with the hidden cameras, over and above the effects of the existing speed camera program.	Outcome = speed Measure = Difference in change in mean speed between experimental and control areas. Measure = Estimated crash reduction per annum	Weighted averages, using time period and unidirectional hypothesis.	a) -1.3km/hr (-2.6 to 0.1) b) -2.3km/hr (-3.1 to -1.4)	a) All roads (post 2 year average) b) Speed camera roads (post 1st year average)

Table 3. Study Outcomes - ITSs *(Continued)*

		Outcome = Crashes Measure = Estimated percent change of trial to control crash ratio	Logistic model of proportion of crashes in trial region cf control region, including season and year - unidirectional hypotheses.	a) -11% (-20% to -1%) b) -17% (-36% to +7%)	Change is in first two years of intervention a) All roads b) Speed camera roads
		Outcome = Injury crashes (fatal + serious) Measure = Estimated percent change of trial to control crash ratio	Logistic model with over-dispersion model of proportion of casualties in trial region cf control region, including season and year -unidirectional hypotheses	-3% (-8% to 3%) a) -19% (-28% to -9%) b) -31% (-50% to -3%)	Change is in first two years of intervention a) All roads b) Speed camera roads

In order to facilitate the comparison of studies as well as to capture the effect of intervention(s) and relate them to control (non-intervention) data, a standardised and well-defined summary measure was devised. The tool selected was based on relative effects, rather than difference in effect, where the outcome after intervention is divided by that before intervention as an expression of the proportional change in the outcome.

Unadjusted data provided by study authors in their tables, text or on graphs was used to present results in relation to speed, numbers speeding, crashes, injuries and fatalities.

CBA studies

The following descriptive summary statistics were used as the outcomes (speed and crash outcomes) for CBAs.

Speed

Relative speed ratio (RSR)

= (average speed post intervention average speed pre intervention) (average speed post control average speed pre control)
When expressed as a percentage, RSR measures the relative percentage change in speed after intervention i.e. relative to control.
Percentage Speeding Relative Rates Ratio (PSRRR)
= (speeding rate post intervention speeding rate pre intervention) (speeding rate post control speeding rate pre control)
When expressed as a percentage, PSRRR measures the relative percentage change in speeding rates after intervention i.e. relative to control.
This applied to the percentage of vehicles speeding or percentage of speeders who were speeding in excess of a speed threshold.

Crashes (all crashes, injurious crashes and fatal crashes)

Relative Crashes Ratio (RCR)
= (crashes post intervention crashes pre intervention) (crashes post control crashes pre control)
When expressed as a percentage, RCR measures the relative percentage change in crash numbers after intervention i.e. relative to that for control. It is the same as the odds of crashing after intervention relative to the same odds if there were no intervention i.e. an odds ratio.
Percentage Crashes Relative Risks Ratio (PCRRR)
= (crash risk post intervention crash risk pre intervention) (crash risk post control crash risk pre control)
When expressed as a percentage, PCRRR measures the relative risk of crashing post intervention, compared with pre-intervention, relative to that for control.
This applies to the percentage of vehicles crashing.

95% confidence intervals (CI) were included in parentheses. For all descriptive summary statistics, values less than 1 indicate a relative reduction, i.e. relative to control result. This reduction can be expressed as a percentage improvement using (1-summary statistic) x 100%.
In the case where the above descriptive statistics or CI were not supplied by the studies, but where there was sufficient other information, these were calculated. Statxact was used if data required exact methodology.
Weighted averages across strata were calculated unless weights were not supplied, in which case crude averages are used. Mean ratios were calculated using geometric means.

ITS studies

In addition to the description of outcomes in the characteristics of included studies table, the results from ITS studies are presented as Table 3. A brief description is given of:

- the underpinning statistical methodology used;
- the outcome measure being investigated and the related measure reported (estimated or calculated by the authors);
- the result(s) and confidence limits as they are reported in the study;
- the mention of any important or defining issues upon which the results are based.

Interrupted time series analyses were performed in five studies (AU VIC 1; CA British Columbia; GB Cambridge; GB Nationwide; NZ Nationwide). The statistical analytical method used ranged from simple monthly averages pre and post intervention to more advanced methods such as ARIMA or multivariate regression using generalised linear models. Within a study, these analyses were performed for different outcomes and for different constructs or strata. For both speed and crashes, most ITS studies reported a calculated or estimated percentage change in the outcome after intervention, which they commonly defined as,
(Post intervention estimate - Pre intervention estimate) x 100 Pre intervention estimate.
Meta-analysis was not appropriate for this review due to pronounced heterogeneity and consequently we could not test for publication bias. For the same reason we were unable to perform any reasonable subgroup analyses on overt versus covert camera issues.

R E S U L T S

Description of studies

See: Characteristics of included studies; Characteristics of excluded studies.
After full text review of all potentially relevant studies, 26 studies met the inclusion criteria. All the studies were observational in nature of which, 22 were controlled before-after trials (CBAs) incorporating a distinct control or comparison group(s) and four were interrupted time series studies (ITSs) with a comparison group(s). Seven studies had several associated studies, which were subsumed in each of the seven primary studies. No randomised controlled trials were found.
As heterogeneity was widespread across studies we have included examples of variations in Table 4 to make it easier for the reader to see the extent of differences between studies.

Table 4. List of variations between studies (some examples)

OUTCOMES REPORTED (number of studies) Speed + Crash outcomes (14) Crash outcomes only (7) Speed outcomes only (5) Halo effects (6)
TYPE OF INTERVENTION (number of studies) Fixed overt cameras (12) Fixed overt and covert cameras (1) Mobile overt cameras (5) Mobile covert cameras (2) Mobile overt and covert cameras (4) Combined fixed and mobile overt cameras (1) Combined fixed and mobile, overt and covert cameras (1)

Table 4. List of variations between studies (some examples) (*Continued)*

SETTING (number of studies) Urban (8) Rural (5) Rural and/or semi-rural (7) Mixed urban/rural/semi-rural (6)
TYPE OF ROAD Highway/motorway (5) Residential (3) Arterial (6) Trunk (2) Various combinations of above road types (10)
SPEED LIMITS (number of studies) Not specified (12) 40km (2) = 60km (1) 50km to 100km (1) 60km (1) > 60km (1) 80km (2) 100km (3) All available speeds Nationwide (3) Miles per hour (mph) speeds for UK and USA
NUMBER OF EXPERIMENTAL (E) AND NUMBER OF CONTROL (C) SITES (number of studies) Number of C sites unclear (3) Number of E + C sites unclear (3) 1E + 1C = (3) 2E + 1C = (1) 3E + 1C = (1) 4E + 4C = (1) 6E + 6C = (1) 7E + 8C = (1) 10E + 2C = (1) 10E + 5C = (1) 12E + 12C = (1) 14E + 4C = (1) 20E + 10C = (1) 24E + 24C = (1) Descriptions of as many as 2,300 E sites in GB Nationwide study and 2500 sites in AU QLD 2 study by end of study periods.
DURATION OF INTERVENTIONS (number of studies) Range from 9 weeks to13 years = 2 years (9) 2 to 4 (4) 4+ to 6 years (7) 4+ to 6 years (7) 6+ to 8 yrs (1) 8+ to 10 years (3)

Table 4. List of variations between studies (some examples) (*Continued*)

> 10+ years (2)
AVERAGE FOLLOW-UP PERIOD POST INTERVENTION (number of studies) Range from 2 weeks to 12 years (years) < 1 year (5) at least 1 year (2) 1 to 2 years (12) 2+ to 4 years (6) 4+ to 6 years (2) 9+ years (1)

As several studies emanated from the same country and some studies had one or more main authors in common, it was decided to name studies according to the official country codes of the International Organisation for Standardisation (ISO-3166).

Fourteen studies reported both speed and crash outcomes (AU NSW 2; AU Tasmania; AU VIC 1; AU VIC 2; CA British Columbia; CA Vancouver; DE Germany; DK Denmark; FI Finland; GB Nationwide; HK Hong Kong; NL Netherlands; NZ Christchurch; NZ Nationwide). Seven studies reported crash outcomes only (AU QLD 1; AU QLD 2; AU VIC 3; GB Cambridge; GB South Wales; GB West London; NO Nationwide) and five studies reported speed outcomes only (AU NSW 1; AU South Australia; CA Toronto; NO Oslo; US Washington DC). Of the included studies, six studies reported halo effects, with three studies describing time halo effects (AU NSW 1; CA Toronto; NO Oslo) two studies reported distance halo effects (AU Tasmania; FI Finland) and one study (AU NSW 2) reported both time and distance halo effects.

Outcome measures in the studies differed considerably and included various definitions and measures of speed, crashes, injuries and deaths. For some studies, results for 'all crashes' may be inclusive of property damage crashes, and it should be borne in mind that injury crashes are not always necessarily a subset of those that are speed related (assuming such crashes can actually be defined). Most studies analysed crash numbers rather than rates and only a few studies provided data on the aggregate (over crashes) of the number of fatalities and number of people, who sustained at least one injury.

Types of interventions varied between studies. Speed enforcement detection devices (SEDs) were described according to whether they were overt or covert, whether they were operated from a fixed or mobile position on the road, or any combination of these four elements. For the purposes of this review, fixed SEDs were defined as speed cameras operating from a fixed mounted position on poles and did not include speed cameras operating from patrol cars or working on temporarily installed poles. The latter, although stationary for a period were often moved from place to place. Thirteen studies assessed the effect of fixed cameras, of which, 12 studies had overt SEDs and one study had both overt and covert SEDs. Eleven studies assessed the effect of mobile camera interventions. Of these, five studies had overt and two had covert SEDs. Four studies had both a mixture of overt and covert SEDs. One study reported the effects from a combination of both fixed and mobile overt SEDs and one study reported the effects of a combination fixed, mobile, overt and covert SEDs. Studies also varied considerably in both the number and duration of intervention events. Interventions were continuous in only two of the studies. Continuous operation was defined as SEDs operating continuously at all experimental sites and did not include SEDs operating continuously at some sites on a random alternating basis.

All included studies took place in countries with a high socio-economic status, with one study each from Denmark, Finland, Germany, Hong Kong, Netherlands, and the USA, two from Norway and two from New Zealand, three from Canada, four from Great Britain and nine from Australia. Eight studies were conducted within an urban setting, five in a rural setting, seven occurred in a rural and/or a semi-rural location and six studies were conducted within a mixed urban/rural/semi-rural environment. This diversity of study locations corresponded with a range of urban and rural speed limits within studies, that varied from 40 kilometres per hour (km/h) through 60 km/h, 80 km/h, 100 km/h and 110 km/h to corresponding speed limits in miles per hour (mph) in the UK and USA. Only five studies described their criteria for speed limit compliance, above which traffic infringements notices were issued.

All included studies were published between 1984 and 2004, with study periods ranging from nine weeks to thirteen years; nine trials had study periods of less or equal to 24 months, four had study periods of 25 to 48 months (2+ to 4 years), seven had study periods of 49 to 72 months (4+ to 6 years), one of 73 to 96 months (6+ to 8 years), three of 97 to 120 months (8+ to 10 years) and two of equal or greater than 120 months (10 years plus). The major focus for studies of the shortest duration was the measurement of halo effects.

More detail about individual studies can be found in the table 'Characteristics of included studies'.

Risk of bias in included studies

Four of the seven criteria outlined in the data collection checklist described by the Cochrane EPOC Review Group were used to establish the methodological quality of the included controlled before-after studies:

1. availability of baseline measurements;
2. appropriate choice of control;
3. protection against contamination between intervention and control site;
4. reliability of outcome measures.

In addition to criteria 1) and 4) above, two other criteria as described by EPOC were used to assess the methodological quality of ITS studies, which were, a clearly defined point in time when the intervention occurred, and at least three data collection points before and after the intervention.
The criteria for CBAs provided twelve key indicators in total, and the criteria for ITS studies provided a total of nine key indicators. Table 5 in the additional tables section of this review details the outcomes for the scoring method used to assess the quality of the included studies. CBA studies were marked as either done, not clear, not done (as described by EPOC) for each of the twelve indicators, and again ITS studies were marked as either done, not clear, not done for each of the nine indicators.
For studies to be then classified as good, fair or poor they had to have scored the following;

Table 5. Methodological Quality of Included Studies

Study I.D.	Done	Unclear	Not done	Quality Score
CBA studies (12 indicators)				Based on: Good = (Done = 10, Not clear = 2, Not done = 0) Fair = (Done = 8, Not clear = 2, Not done = 2) Poor = (< than 8 done)
AU NSW 1	5	5	0	Poor
AU NSW 2	11	1	0	Good
AU QLD 1	7	5	0	Poor

Table 5. Methodological Quality of Included Studies *(Continued)*

AU QLD 2	10	2	0	Good
AU South Australia	9	3	0	Fair
AU Tasmania	9	3	0	Fair
AU VIC 2	11	1	0	Good
AU VIC 3	10	1	1	Fair
CA British Columbia	6	6	0	Poor
CA Toronto	10	2	0	Good
CA Vancouver	8	4	0	Fair
DE Germany	6	5	1	Poor
DK Denmark	7	0	5	Poor
FI Finland	5	5	2	Poor
GB South Wales	6	6	0	Poor
GB West London	6	4	2	Poor
HK Hong Kong	4	6	2	Poor
NL Netherlands	4	4	4	Poor
NO Nationwide	10	2	0	Good
NO Oslo	10	2	0	Good
NZ Christchurch	9	3	0	Fair
US Washington DC	8	3	1	Fair
Time series designs (9 indicators)				Based on: Good = (Done = 7, Not clear = 2, Not done = 0) Fair = (Done = 6 Not clear = 2 Not done = 1) Poor = (< than 7 done)
AU VIC 1	7	1	1	Good
GB Nationwide	6	3	0	Fair
GB Cambridge	7	1	1	Fair
NZ Nationwide	7	1	1	Fair

CBA studies: Good = (Done = 10, Not clear = 2, Not done = 0), Fair = (Done = 8, Not clear = 2, Not done = 2), Poor = (< 8 Done).

ITS studies: Good = (Done = 7, Not clear = 2, Not done =0), Fair = (Done = 6, Not clear = 2, Not done = 1), Poor = (< 6 Done).

The overall methodological quality was poor. Of the 26 studies only seven studies were scored as being of good quality. Of the remaining 19 studies, ten were scored as fair and nine were scored as poor.

See the notes section in the 'Characteristics of included studies' table for concerns with specific studies.

Effects of interventions

Calculated summary statistics and brief descriptions of speed and crash outcomes were presented for individual trials where appropriate.

Speed

All studies except one (AU VIC 1) reported an absolute reduction in average speeds post intervention. Reductions were reported either as mean speeds, 'average speeds' or as median speeds. Mean speeds were reported by seven studies (AU NSW 2; AU VIC 1; CA Vancouver; DK Denmark; NZ Christchurch; NZ Nationwide; US Washington DC), 'average' speeds by five studies (AU Tasmania; AU VIC 2; GB Nationwide; NL Netherlands; NO Oslo) and median speeds by two studies (AU South Australia; DE Germany). The standardised summary statistic (Relative Speed Ratio) could be calculated for five studies (AU NSW 2; AU Tasmania; NL Netherlands; NZ Nationwide; US Washington DC). The Relative Speed Ratio ranged from 0.85 to 0.99, indicating that relative post-pre reductions were an improvement on control by between 1 to 15%. Confidence intervals could be calculated for three of the five studies (AU Tasmania; NL Netherlands; US Washington DC) and were narrow due to the large numbers of vehicles.

Mean speed

Absolute reductions in reported mean speeds varied from no change in Victoria (AU VIC 1) to a 2.8 km/h reduction reported by the Vancouver study (CA Vancouver). An absolute reduction in mean speed of 2.3 km/h at speed camera sites in year one was reported for the Midland Region of New Zealand. DK Denmark reported a 2.4 km/h reduction and New South Wales (AU NSW 2) a similar absolute reduction in mean speeds of 2 to 3km/h. However in New South Wales, this reduction in mean speed was seen at both experimental and control sites (relative speed ratio = 0.99). CA Vancouver recorded a 2.8 km/h absolute reduction in mean speed at its monitoring site, 2 km from the intervention site, and the US Washington DC study reported a percentage pre/post reduction of 14% in mean speed. The post-pre speed ratio, relative to controls, was 0.85 (0.847 to 0.857) indicating a significant relative improvement, with a reduction of 15% compared to the control data. AU VIC 1 reported no absolute change in mean speed and Christchurch New Zealand (NZ Christchurch) reported a small absolute mean speed reduction of 0.8 km/h for four years after the intervention.

Average speed

Norway (NO Oslo) reported average speed absolute reductions of 0.9 km/h to 4.8 km/h for all times of day. NL Netherlands reported an average speed absolute reduction of 3 km/h in the first three months post intervention, to 5 km/h at six months. Although the post-pre speed ratio was only a 6% improvement compared with controls, the result was significant (relative speed ratio 0.936 (95% CI 0.932 to 0.941). Victoria (AU VIC 2) reported an absolute reduction of 3.4 km/h and AU Tasmania 3.6 km/h, which translates to a non-significant reduction of 4% compared to controls. The United Kingdom (GB Nationwide) reported that about an 8% reduction in pre/post average speed was achieved long term for fixed camera sites in rural areas and a 15% pre/post reduction for fixed speed camera sites in urban areas.

Median speed

Median speeds were reported by South Australia (AU South Australia) with an absolute reduction of 5km/h on experimental roads, and DE Germany, which recorded an absolute reduction in median speeds of 40 km/h and 28 km/h in car lanes, with a 23 km/h reduction in the truck lane after ten years of continuous enforcement.

Percentage speeding

Speed was also reported as either absolute reductions in the percentage of speeding vehicles, as percentage speeding reductions over various speed limits, or as reductions in percentages of top end speeders. The standardised summary statistic, PSRRR, (% speeding Relative Rates Ratio) could be calculated for six studies (AU NSW 1; CA British Columbia; FI Finland; NL Netherlands; NZ Nationwide; US Washington DC) and ranged from 0.35 to 0.86, indicating reductions relative to controls.
An absolute reduction in the proportion of speeding vehicles (drivers) ranged from around 10% in Norway (NO Oslo) and DK Denmark to 26%, 31% and 70% in the Netherlands, CA British Columbia and New South Wales (AU NSW 1) respectively. For British Columbia and New South Wales this translates to a relative reduction of 47% and 22% compared with the control result (PSRRR 0.53 and 0.78, respectively, no CI). For NL Netherlands, the relative reduction is significant compared to that for the controls, where the PSRRR 0.43 (95%CI 0.41 to 0.46). In FI Finland a 10% reduction in speeding vehicles on 80 km/h roads, and a 7% reduction on 100km/h roads was reported. The overall PSRRR is 0.66, indicating that the speeding rate reduction was relatively less than that for controls, but confidence limits were incalculable.
An 82% absolute reduction in the proportion of vehicles exceeding the speed limit by more than 10 mph was recorded in the US

Washington DC study, and the PSRRR was 0.35 (95% CI 0.30 to 0.40) indicating that the reduction was significantly improved over that for controls. HK Hong Kong reported an absolute reduction of 65% in the proportion of vehicles in excess of 15 km/h or more. The Victorian study (AU VIC 1) reported decreases in percent speeding from 11.27% to 5.5% of greater than 15 km/h, and from 3.33% to an average of 1.85% of greater than 30 km/h, in 60 km/h zones. In 75 km/h zones these decreases in percent speeding ranged from 8.3% to 4.2% for those in excess of 15 km/h over, and from 2.47% to an average of 1.3% for those exceeding the speed limit by 30 km/h or more. No absolute speed reduction occurred on 100 km/h roads in Victoria.

Halo effects

Two measures of the effect of enforcement on speed are the time halo and distance halo. As the characteristics of studies reporting halo effects varied in terms of location, duration of intervention, data collection and measurement, a brief overview of each of the six studies that reported halo effects follows.

New South Wales (AU NSW 1) - Outcome = Time halo of at least two days.

Study period from February 1982 for a period of nine weeks.

Two experimental sites with police car stationed at both sites. The primary survey point was 300 metres downstream at site two where the experiment was covert. The secondary point was 200 metres upstream at site one, where the experiment was overt. The sites were in two lane sub-arterial urban roads with a 60km/h speed limit. Enforcement symbol in place and enforcement period was for one hour in the morning 8.00am to 9.00am and one hour in the afternoon 2.00pm to 3.00pm in February and March 1982.

Oslo (NO Oslo) - Outcome = Time halo up to eight weeks during daylight hours, In 80 km/h zones three out of five measured time intervals showed a time halo effect of six weeks.

Study period August 1991 to December 1991.

Five patrols each consisting of one marked vehicle and two police officers, average nine hours of enforcement per day (388 hours of enforcement in six weeks). Continuous speed measurement for 24 hours every day during the sixteen week study period. Experimental road was a 35 km stretch of undivided two lane road in a semi-rural area divided into six sections for the experiment (control similar).

Toronto (CA Toronto) - Outcome = Three day time halo for one dose of enforcement.

At least six days time halo for five consecutive doses of enforcement.

Study period October 1979 to December 1979; five week study. Data collection by 2.5 hours per day on weekdays of five consecutive weeks for each location. Automatic speed traffic data recorders were used. Four experiments are described. Each experiment consisted of measuring speed of vehicles before, during and after enforcement took place. Each of the four experimental sites had an 'upstream' enforcement and a 'downstream' measurement site (latter was 1km to 2.5 km from the site of enforcement) In experiment one the police van was visible in advance. In experiment two to four the police vehicle was visible to the driver only 200 to 300m before passing the speed sensors. The four experiments differed in the number of days of enforcement (see Additional tables, Table 1; Table 2; Table 3).

New South Wales (AU NSW 2) - Outcome = Time halo at least one day after enforcement, distance halo up to 14 km downstream.

Study period December 1986 to March 1987 for speed.

Thirty-two sites of enforcement, aerial speed surveillance. From the 32 rural sites in place by December 1986, 10 experimental sites were chosen. Five matched control sites were selected.

Tasmania (AU Tasmania) - Outcome = Distance halo up to 22 km.

Total study length was two years between December 1984 to December 1986.

Single overt police car, random scheduling low intensity enforcement for two hours per day, seven days per week at sites. Location was three rural or main roads with a 110 km/h speed limit divided into one km sections.

Finland (FI Finland) - Outcome = Distance halo 3 km upstream to two km downstream.

Study period April 1990 to December 1993.

Cameras rotated randomly between 12 camera poles at a distance of 1.5 km to 7 km from each other in one direction of enforcement. Duration of surveillance from 8 to 36 hours (operation time 8065 hours from April 1992 to December 1993).

Crashes

All studies reported a reduction in road traffic crashes and crashes resulting in injury. The magnitude of this effect in crash outcomes varied considerably across studies. Twenty-one studies reported crash outcomes of which, localised effects (that is, in the vicinity of camera sites) were reported by seven studies (AU NSW 2; AU QLD 2; AU VIC 1; AU VIC 3; CA Vancouver; GB Cambridge; GB Nationwide). Fourteen studies reported on generalised effects (AU QLD 2; AU Tasmania; AU VIC 1; AU VIC 2; CA British Columbia; CA Vancouver; DK Denmark; FI Finland; GB Nationwide; GB West London; HK Hong Kong; NL Netherlands; NZ Christchurch; NZ Nationwide) with three of these studies (AU VIC 1; CA Vancouver; GB Nationwide) reporting both localised and generalised effects.

The standardised summary statistic, relative crash ratio that is, relative to controls, could be calculated for ten of these studies. For all crash types reported by six studies (AU NSW 2; AU Tasmania; CA British Columbia; HK Hong Kong; NL Netherlands; NZ Christchurch) this statistic ranged from 0.64 to 0.95, indicating improved reductions compared with those for controls from between 5% to 36%. Injury crashes were reported by eight studies (AU NSW 2; AU Tasmania; DE Germany; FI Finland; HK Hong Kong; NL Netherlands; NO Nationwide; NZ Christchurch). Relative crash ratio ranged from 0.66 to 0.86 (improvements of 14% to 34%). In all cases confidence intervals could be calculated. There was only one study (DE Germany) in which there was enough information to calculate the summary statistic PCRRR, which was 0.44, CI incalculable.

Localised crash effects

Localised effects for all crashes showed pre/post percent reductions of 14% (CA Vancouver), 22% (AU NSW 2), and 71.6% (AU VIC 3). For crashes resulting in deaths or serious injuries pre/post percent reductions of 40% (GB Nationwide) and 45% (AU QLD 2) were reported in the vicinity of camera sites. Whilst a pre/post reduction of 33% in personal injury crashes at camera sites was found in one large study (GB Nationwide) no significant reduction in injury crash frequency or severity was found within one km of camera sites, either in urban or rural areas, in another sizeable study in Victoria, Australia (AU VIC 1) as a result of camera site operations. However, a localised effect of 8.4% in pre/post injury crash reduction was found for all urban roads as a result of the influence of receipt of traffic infringement notices (TINs) in the latter study. The Cambridge study reported a pre/post 45.74% reduction in injury crashes within 250m from camera sites and a lesser but still significant 20.86% reduction inside a 2 km radius from the camera.

Generalised crash effects

Outcomes reported were pre/post reductions in overall crashes, ranging from 9% (NZ Christchurch) to 35% (NL Netherlands), with a reduction of 9.17% (NZ Christchurch) 11% (NZ Nationwide) 12.4% (GB West London) 16% (CA British Columbia) 19% (FI Finland) 21% (AU QLD 2) and 35% (NL Netherlands). Relative crash rates (RCR) that is relative to controls, were calculated for CA Vancouver 0.95, HK Hong Kong 0.74, AU Tasmania 0.88, AU NSW 2 0.78, NL Netherlands (Phase 3) 0.64, NL Netherlands (primary study) 0.64, and NZ Christchurch 0.91. Only the NL Netherlands results were significant.

Injury related crashes

Percent pre/post injury crash outcomes reported, ranged from 7% (AU VIC 2) to 30% (AU VIC 1), with a reduction of 7% (AU VIC 2) 11% (CA British Columbia) 19% (CA Vancouver) 21% (DK Denmark) 23% (HK Hong Kong) and within 60 km/h zones in Victoria (AU VIC 1), a 30% pre/post injury crash reduction in urban, and a 20% reduction in rural areas. Relative crash rates (RCR), relative to controls were calculated for NO Nationwide 0.79, HK Hong Kong 0.86, AU Tasmania 0.78, New South Wales (AU NSW 2) 0.81, FI Finland 0.81, NL Netherlands (Phase 3) 0.79, NL Netherlands (primary) 0.66, and NZ Christchurch 0.69 and Victoria (AU VIC 3) 0.98. Only the results for AU Tasmania and Norway were significant.

Fatality related crashes

There was a reported 17% (CA British Columbia) and a 13% (AU VIC 2) pre/post reduction in crashes resulting in fatalities. For serious injury and fatality crashes combined, pre/post reductions of 31% (GB West London) 40% (GB Nationwide) and 58% (AU Tasmania) were reported. The reduction in AU Tasmania was an improvement of 26% compared with controls where RCR 0.72 (95% CI 0.36 to 1.08). New South Wales (AU NSW 2) reported no fatality crashes at all post-intervention. For HK Hong Kong, the relative crash rate for fatal crashes was 0.33 (95% CI 0.01 to 4.60) which was a 67% improvement compared with controls, however there were only four fatal crashes in total reported at the intervention site.

Further details of both speed and crash outcomes can be seen in the characteristics of included studies and results, in a standardised format, are presented in Table 1 and Table 2.

Interrupted time series

Interrupted time series analyses were reported for the outcomes of speed, speeding and crash data in studies from four countries (AU VIC 1(Phase I and II; state-wide and metropolitan); CA British Columbia; GB Cambridge; NZ Nationwide). The statistical analytical method used ranged from simple monthly averages pre and post intervention to more advanced methods like ARIMA or multivariate regression using generalised linear models. Within a study, these analyses were performed for different outcomes and for different constructs or strata. Most studies reported results as estimated percentage changes in the outcome after intervention and the results can be viewed in Table 3. Times series analysis was also used to analyse the head-count of crash victims. CA British Columbia estimated a drop in crash victims of -31 to -140, while NZ estimated percentage changes in casualties, compared with control, of -19% and -31%. Finally, in AU VIC 1 (Phase 2), the ratio of fatal plus serious crashes to minor crashes (severity), was analysed using a multiplicative model. Significant reductions in crashes were reported (P<0.01) on a log scale linked to increases in traffic infringement notices (TINs) issued and publicity, whilst significant reductions in severity were attributable to increases in TINs issued and hours of speed camera operation.

DISCUSSION

The results of this systematic review show that automatic speed detection enforcement devices reduce road traffic crashes and related road injuries and deaths. However, studies of a higher quality need to be done, which are well designed, are more homogenous in nature and have methodological rigour. This is essential to provide a stronger evidence base, necessary to support claims for the effectiveness of automatic speed enforcement.

The methodological quality of the included studies was generally poor. Although we found no randomised controlled trials, in an effort to control for confounding, we only included studies in this review that also had control or comparison areas and that had adequate before and after periods. With the exception of studies of short duration, whose main outcome focus was the evaluation of halo effects, all the included studies collected at least one year of 'before 'data and one year of 'after' data, with eight studies having at least two years of 'before' data and a follow-up period of at least two years.

Randomised controlled trials (RCTs) offer the highest level of evidence, yet we found no studies using this type of study design. We wondered why traditional randomised controlled trials or cluster RCTs had not been utilised. Automatic enforcement is often introduced at sites, based on their history of high rates of speed related crashes. In these cases it may be considered difficult to ethically randomise intervention to some traffic 'hot-spots' and not to others, when the intervention is expected to be worthwhile. For countries that restrict camera deployment to high crash locations it would be worthwhile expanding the location criteria, so that conducting RCTs, in order to obtain the best evidence might be possible.

Countries currently considering introducing speed cameras have a unique opportunity to plan the deployment of speed cameras in such a way that they can build the solid evidence base needed. Well-executed randomised controlled trials, using a matched pair and cluster design, as well as quasi-experimental research designs such as, controlled before-after trials (using matched comparison groups) and interrupted time series studies could be done in these circumstances. Firstly a lengthy pre-deployment stage is necessary, where careful collection of speed and crash data is performed under pre-specified transparent guidelines and measures. However difficult, there is a need for international standardization of data collection methods, including standards on how best to measure speeds and collect crash data, so that studies can be compared. Careful data collection needs to continue during the intervention period and for a lengthy follow-up period after intervention. A controlled introduction of automatic enforcement methods is important with careful futuristic planning and anticipated outcomes. For randomised controlled trials a large sampling framework of similar sites could be used to randomise the intervention and control arms.

Assessment of the quality of non-randomised controlled trials is problematic. After an extensive review of the quality tools available, we decided a modified version of the quality assessment process, as developed by the Cochrane Effective Practice and Organisation of Care Review Group best suited the evaluation of the studies under review. This necessitated many preliminary meetings to agree on the relative importance and interpretation of each element of the quality criteria. For example, it is well known that the number of potential confounding variables in road safety evaluation studies is very large. Although we looked for how studies controlled or adjusted for any potential confounding variables, our main focus regarding potential confounders was on three variables known to be important in road safety evaluations i.e. regression to the mean, long term trends and changes in traffic volumes (Hauer 1997). Regression to the mean (RTM) denotes the tendency for an abnormally high number of crashes to return to values closer to the long term mean; conversely abnormally low numbers of crashes tend to be succeeded by higher numbers. RTM occurs as a result of random fluctuation in the recorded number of crashes around the long-term expected number of crashes. Automatic enforcement is often introduced at sites based on their history of high rates of speed related crashes. It is likely that these crash frequencies were at the high end of the naturally occurring random fluctuations, and in subsequent years these sites will experience lower numbers. We checked whether studies had controlled for RTM and in cases where studies did not control for RTM, we assessed where possible, if RTM was likely to be a confounding factor in that particular study.

Based on the quality criteria used to assess the studies included in this review, the level of evidence within this review was appraised as being relatively weak. A previous systematic review also noted the weak level of evidence available (Pilkington 2005).

Most studies did not have adequate control or discussion of potential confounders. Only a few studies controlled for RTM, long term trends in crash rates and changes in traffic volumes. There is a need for better vehicle exposure/traffic volume information over time, given the importance of taking into account changes in exposure when analysing the effects of road safety programs. This is particularly important in light of the fact that studies available in this field are of a quasi-experimental design, where the adequacy and appropriateness of comparison/control areas is often questionable.

Most studies only controlled for or described a few, if any, of many other factors. influencing the frequency of road crashes, such as, seasonality, time of day, changes in road design, speed limits, traffic volumes, and levels of road safety publicity.

Many road safety authorities believe speed management interventions work best in concert, thus, enforcement is often one of many other road safety interventions operating at the same time. We have made every effort to deal with this by stipulating in our inclusion criteria that enforcement had to be the major intervention focus where co-interventions existed, and by excluding any studies where the effect of enforcement could not be differentiated from the effects of other intervention measures.

We would have liked to have seen much more information on the comparison/control sites to help us judge how well experimental and control sites were or could be matched. With the exception of a few studies, much of this information was missing. It was brought to our attention by a couple of studies that it is now more difficult, if not impossible, to find matching controls in some places, where the use of automatic enforcement is widespread and in use for periods as long as ten years. This reiterates the fact that we need to depend on new countries and places, where automatic enforcement is not widely used to provide well-designed studies.

All studies meeting the criteria for inclusion in this review were conducted in high-income countries. This limits the generalisability of the findings. Speed cameras are beginning to be introduced in middle and low-income countries. The findings of studies from high-income countries cannot be assumed to apply to these countries. However, a unique research opportunity exists for many of these countries to conduct studies, where, the subject of speed cameras is not politicized. These studies can be informed by the strengths and weaknesses of the research to date.

Much of road safety research is published in the grey literature. Every possible effort was made to find all relevant controlled trials, however unlike medical databases, which include terms describing the study methodology among its indexing; road safety databases have a very limited range of indexing terms, which made the identification of appropriate studies difficult. A need exists now for authors to adequately describe the study design in their reports and for editors to demand this, so that improvements in thesaurus terms can be made to road safety databases.

Although studies were conducted in varied rural and urban locations, only a few studies reported on the frequency of injurious crashes for different categories of road user (pedestrians, cyclists, motorcyclists, vehicle occupants) therefore, it was not possible to examine the effect of automatic enforcement on road trauma by road user category

There was widespread heterogeneity across studies, with variations in speed limits, types and duration of interventions, length of follow up periods, setting of interventions, outcome measures and numbers of intervention and control sites. These factors made it difficult to integrate and summarise the evidence. We could not evaluate publication bias due to heterogeneity. In relation to statistical analysis, methods used varied from the application of basic univariate analysis through to more rigorous statistical methodology for the interrupted time series data. In some instances authors had developed in-house methods for analysing their data. Furthermore, the way in which outcomes were reported varied extensively across studies and one of the difficulties we faced was finding the basic information needed to calculate a standardised summary statistic. It is recommended that there be some consensus as to the expression of outcomes, for example, crash rates per volume of traffic; percentage pre/post changes in speed and percentage pre/post changes relative to controls, all with the accompanying 95% confidence intervals. Until this occurs and other issues relating to heterogeneity are addressed meta-analysis is not possible.

Realistically some heterogeneity will persist across studies as researchers need to work in conjunction with government and local authorities to address such issues as speed limits, road design, traffic flow, co-interventions. At analyses stage, statistical models can be adjusted for these factors. Heterogeneity can also be dealt with by the use of sub-group analysis. However, this opportunity is dependent on the collection and provision of good quality data.

A sizeable body of literature exists which convincingly demonstrates the relationship between relative and absolute excess in speed and road traffic crashes, injuries and deaths. The role for regulating, monitoring, and enforcing speed limitations is not in doubt. The principal problem with traditional enforcement systems is that aberrant speeding behaviour is widespread and therefore the use of automatic SEDs is considered the most efficient way to significantly increase both detection and apprehension rates (Zaal 1994). The main issue then is whether speed enforcement, as currently practiced, reduces road traffic crashes, injuries and deaths. It is speculative whether more intense speed enforcement and higher penalties would be more effective, particularly for more substantial deviations from the posted speed. However, the rationale of using speed enforcement detection devices to impose safe speeds and limit maximum speeds, to improve road safety is unequivocal.

The possibility of using these devices in concert with the developing field of Intelligent Speed Adaptation (ISA) systems (Carsten 2002) to further enhance road safety was not within the scope of this current review, but merits further research.

In conclusion, despite the methodological limitations of the studies reviewed, the consistency of reported positive reductions in speed and crash outcomes across all studies show that speed enforcement detection devices (SEDs) are a rational intervention for reducing the number of road traffic crashes, injuries and deaths.

AUTHORS' CONCLUSIONS

Implications for practice

Speed enforcement detection devices are a rational intervention for reducing road traffic injuries and deaths in both rural and urban settings. However, more rigorous research, which is consistent and comparable is needed to further strengthen the evidence base.

Implications for research

An extensive literature exists on issues pertaining to automatic speed enforcement. However when searching for studies we found numerous uncontrolled before after studies, many studies without any 'before' data and no randomised controlled trials. Only 26 studies met our inclusion criteria. Interventions using automatic speed enforcement devices need to be properly evaluated using well designed controlled trials, so that their effectiveness can be more accurately assessed.

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R E F E R E N C E S

References to studies included in this review

AU NSW 1 *{published data only}*

Armour M. The effect of police presence on urban driving speeds. *Australian Road Research* 1984;**14**(3):142–8.

AU NSW 2 *{published data only}*

Cairney PT. The effect of aerial enforcement on traffic speeds. Proceedings 14th ARRB Conference, Part 4. 1988:126–32.
* Kearns IB, Webster KA. The effect of aerial speed enforcement on traffic crashes. Traffic Authority of New South Wales, Research Note RN 4/88 1988:1–12. [: ISSN 0314–9846, ISBN 0–7240–7291–8]

AU QLD 1 *{published data only}*

Newstead SV, Cameron MH, Leggett LMW. The crash reduction effectiveness of a network-wide traffic police deployment system. *Accident Analysis and Prevention* 2001;**33**(3):393–406.

AU QLD 2 *{published data only}*

* Newstead SV, Cameron M. Evaluation of the crash effects of the Queensland speed camera program. Monash University Accident Research Centre, Report No. 204 2003:1–35.
Walsh D, Wessling G. Speed Cameras: Queensland last off the blocks but is it leading the race?. 3rd National Conference on Injury Prevention and Control. Brisbane, Queensland, Australia. 1999:79–83.

AU South Australia *{published data only}*

* Cairney P T, Fackrell H L. The effects of a 40km/h local area speed limit on traffic behaviour and community perceptions and opinion. Australian Road Research Board -Research Report ARR No 243 1993:1–23. [: ISBN 0 86910 600 7, ISSN 0518 –0728]
Cairney PT, Harwood CW. Experience with local area speed limit in Unley, South Australia. Proceedings 17th ARRB Conference, part 5. 1994:323–40.

AU Tasmania *{published data only}*

Leggett LMW. The effect on accident occurrence of long-term low intensity police enforcement. 14th Australian Road Research Board (ARRB) Conference. 1988; Vol. Part 4:92–104.

AU VIC 1 *{published data only}*

* Cameron M, Cavallo A, Gilbert A. Crash-based evaluation of speed camera program in Victoria 1990 -1991, Phase 1: General effects. Phase 2: Effects of program mechanisms. Monash University Accident Research Centre (MUARC) Victoria 3800, Australia 1992; Vol. Report No 42:1–76.
Newstead S, Mullan N, Cameron M. Evaluation of the speed camera program in Victoria 1990-1993. Phase 5: Further investigation of localised effects on casualty crash frequency and severity. Monash University Accident Research Centre (MUARC) Victoria 3800, Australia 1995; Vol. Report No 78:1–27.
Rogerson P, Newstead S, Cameron M. Evaluation of the speed camera program in Victoria 1990 -1991, Phase 3: Localised effects on casualty crashes and crash severity, Phase 4: General effects on speed. Monash University Accident Research Centre (MUARC) Victoria 3800, Australia 1994; Vol. Report No 54:1–41.

AU VIC 2 *{published data only}*

* Diamantopoulou K, Corben B. The impact of speed camera technology on speed limit compliance in multi-lane tunnels. Road Safety Research, Policing and Education Conference. Adelaide, South Australia. 2002. [: ISBN 1–876346–46–9 ISBN 1–876346–46–9]
Donnelly T. Application of system engineering techniques to optimise benefits of fixed speed cameras. Tenix Solutions Melbourne, Victoria, Australia 2003.

AU VIC 3 *{published data only}*

* Diamantopoulou K, Cameron M. An evaluation of the effectiveness of overt and covert speed enforcement achieved through mobile radar operations. Report no 187, Monash University Accident Centre (MUARC) March 2002:xiv + 42. [: ISBN 0 7326 1486 x4]
Diamantopoulou K, Cameron M, Shtifelman M. Evaluation of moving mode radar for speed enforcement in Victoria 1995-1997. Monash University Accident Research Centre (MUARC) Victoria, Australia 1998.
Diamantopoulou K, Cameron M, Shtifelman M. The effect of mobile radar devices and associated publicity on road trauma in Victoria. Road Safety Research, Policing and Education Conference. Wellington, New Zealand. 1998.

CA British Columbia *{published data only}*

Chen G, Wilson J, Meckle W, Cooper P. Evalaution of photo radar program in British Columbia. *Accident Analysis and Prevention* 2000;**32**:517–26.

CA Toronto *{published data only}*

Hauer E, Ahlin FJ. Speed enforcement and speed choice. *Accident Analysis and Prevention* 1982;**14**(4):267–78.

CA Vancouver *{published data only}*

Chen G, Meckle W, Wilson J. Speed and safety effects of photo radar enforcement on a highway corridor in British Columbia. *Accident Analysis and Prevention* 2002;**34**:129–38.

DE Germany *{published data only}*

Lamm R, Kloeckner JH. Increase of traffic safety by surveillance of speed limits with automatic radar devices on a dangerous section of a German autobahn: a long term investigation. *Transportation Research Record* 1984;**974**:8–16.

DK Denmark ***{published data only}***
Agustsson L. Automatic Speed enforcement. The Danish pilot project [Automatisk hastighedskontrol, Rapport 210]. Danish Road Directorate 2001.

FI Finland ***{published data only}***
Makinen TE. Halo effects of automatic speed enforcement. Technical Research Centre of Finland (VTT) 2001:341–5.

GB Cambridge ***{published data only}***
* Hess S. An analysis of the effects of speed limit enforcement cameras with differentiation by road type and catchment area. Centre for Transport Studies, Imperial College, London UK (MPhil project) 2003:1–14.
Hess S, Polack J. An analysis of the effects of speed limit enforcement cameras on accident rates. Transportation Research Record, Centre for Transport Studies, Imperial College, London UK 2003:1–16.

GB Nationwide ***{published data only}***
* Gains A, Heydecker B, Shrewsbury J, Robertson S. The national safety camera programme -Three-year evaluation report. Department of Transport. Road Safety Division. London UK 2004:1–110.
Gains A, Humble R, Heydecker B, Robertson S. A cost recovery system for speed and red-light cameras - Two year pilot evaluation. Department of Transport. Road Safety Division. London UK 2003; Vol. Version 3:1-1 to J -1.

GB South Wales ***{published data only}***
Christie SM, Lyons R A, Dunstan FD, Jones SJ. Are mobile speed cameras effective?A controlled before and after study. *Injury Prevention* 2003;**9**(4):302–6.

GB West London ***{published data only}***
Highways Agency's London Network and Customer Services (LNCS). West London speed camera demonstration project. London Accident Analysis Unit (LAAU), London Research Centre (LRC) 1997:1–45.

HK Hong Kong ***{published data only}***
Hung-Leung C. Speed enforcement camera systems in Hong Kong. HKSAR, Transport Department Hong Kong 2000:386–94.

NL Netherlands ***{published data only}***
Oei HL. Automatic speed management in the Netherlands. *Transportation Research Record* 1996;**1560**:57–64.
* Oei HL, Polak PH. Effect of automatic warning and enforcement on speed and accidents: Results of an evaluation study in four Dutch provinces [Effect van automatische waarschuwing en toezicht op snelheid en ongevallen: Resultaten van een evaluatie–onderzoek in vier Provincies]. Leidschendam,Institute for Road Safety Research SWOV, Netherlands 1992; Vol. R–92–23.

NO Nationwide ***{published data only}***
Elvik R. Effects on accidents of automatic speed enforcement in Norway. *Transportation Research Record 1595* 1997;**1597**:1–19.

NO Oslo ***{published data only}***
Vaa T. Increased police enforcement: Effects of speed. *Accident Analysis & Prevention* 1997;**29**(3):373–85.

NZ Christchurch ***{published data only}***
Tay R. Do speed cameras improve road safety?. Traffic and transportation studies: International conference on traffic and transportation studies. Beijing, China. July 2000:44–57.

NZ Nationwide ***{published data only}***
* Keall MD, Povey LJ, Frith WJ. Further Results from a Trial Comparing a Hidden Speed Camera Programme with Visible Camera Operation. *Accident Analysis and Prevention* 2002;**34**(6): 773–7.
Keall MD, Povey LJ, Frith WJ. The relative effectiveness of a hidden versus a visible speed camera programme. *Accident Analysis and Prevention* 2001;**33**(2):277–84.
Povey LJ, Frith WJ, Keall MD. An investigation of the relationship between speed enforcement, vehicles speeds and injury crashes in New Zealand. Road Safety Research, Policing and Education Conference. Land Transport Safety Authority, New Zealand. 2003: 1–11.

US Washington DC ***{published data only}***
Retting RA, Farmer CM. Evaluation of speed camera enforcement in the District of Columbia. Transportation Research Record 1830 2003, issue 03–4012:34–7.

References to studies excluded from this review

Al Maseid 1997 ***{published data only}***
Al Maseid HR. Effect of police enforcement on drivers behaviour. VTI Conference: Traffic Dafety on two Continents, Lisbon, Portugal. Sept 22–24,1997; Vol. 9A, Part 8:37–58.

Ali 1997 ***{published data only}***
Ali SY, Al-Saleh O, Koushki PA. Effectiveness of automated speed monitoring cameras in Kuwait. *Transportation Research Record* 1997;**1595**:20–6.

Bellotti 2001 ***{published data only}***
Bellotti P. Gloucester safer city project. Department of Transport UK TRL - Dumas work package 9 2001.

Benekohal 1993 ***{published data only}***
Benekohal RF, Resende PTV, Zhao W. Temporal speed reduction effects of drone radar in work zones. *Transportation Research Record* 1993;**1409**:32–41.

Bourne 1993 ***{published data only}***
Bourne M, Cooke R. Victoria's speed camera program. *Crime Prevention Studies* 1993;**1**:177–92.

Brimson 2002 ***{published data only}***
Brimson T, Anderson R. Fixed red light and speed cameras in Canberra: Evaluating a new digital technology. RS2002 Conference. Canberra, ACT, Australia, 2002:401–9. [: ISBN 1–876346–46–9]

Cameron 2003 ***{published data only}***
Cameron M, Newstead S, Diamantopolou K, Oxley P. The interaction between spped camera enforcement and speed-related mass media publicity in Victoria. Monash University Accident Research Centre (MUARC), Victoria, Australia 2003, issue Report 201.

Casey 1993 ***{published data only}***
Casey SM, Lund AK. The effects of mobile roadside speedometers on traffic speeds. *Accident Analysis and Prevention* 1993;**25**(5): 627–34.

Chin 1999 *{published data only}*
Chin HC. An investigation into the effectiveness of the speed camera. Proceedings of the Institution of Civil Engineers Transportation. Journals Dept, Thomas Telford Ltd, Thomas Telford House, 1 Heron Quay, London E14 4JD, 1999; Vol. 135: 93–101. [: Paper 11733]

Diamantopoulou 1998 *{published data only}*
Diamantopoulou K, Cameron M, Shtifelman M. The effect of mobile radar devices and associated publicity on road trauma in Victoria. Road Safety Research, Policing, Education Conference. Wellington, New Zealand. 1998.

Ha 2003 *{published data only}*
HA TJ, Kang JG, Park JJ. The effects of automated speed enforcement systems on traffic flow: Characteristics and accidents in Korea. *Institute of Transportation Engineers ITE journal* 2003;**73**: 28–31.

Hakkert 2000 *{published data only}*
Hakkert AS, Gitelman V, Cohen A, Doveh E, Umansky T. The evaluation of effects on driver behavior and accidents of concentrated general enforcement on interurban roads in Israel. *Accident Analysis and Prevention* 2001;**33**:43–63.

Holland 1996 *{published data only}*
Holland CA, Connor MT. Exceeding the speed limit: An evaluation of the effectiveness of a police intervention. *Accident Analysis and Prevention* 1996;**28**(5):587–97.

Hook 1995 *{published data only}*
Hook D, Kirkwood A, Evans D. Speed cameras in Oxfordshire. *Highways and Transportation* 1995;**42**(2):11–3.

Hooke 1996 *{published data only}*
Hooke A, Knox J, Portas D. Cost benefit analysis of traffic light and speed cameras. Police Research Group. London 1996, issue Police Research Series Paper 20:1–58.

Johannessen 2002 *{published data only}*
Johannessen S. New strategies and methods for speed management in Norway. 15th ICTCT Conference, Brno, Republic of Czechoslovakia. Oct 24–25, 2002:1–12.

Lund 1977 *{published data only}*
Lund HV, Brodersen F, Jorgensen NO. A study of the effects of police enforcement on driver behaviour [Radet for Trafiksikkerhedsforskning: Trafikantadfaerd under skaerpet politiovervagning Rapport 19, Kovenhavn]. Copenhagen, Denmark 1977:7–98. [: ISBN 87–7327–005–9]

Mackie 2003 *{published data only}*
Mackie A, Wells P. Gloucester safer city: Final report. Road Safety Division, Department of Transport 2003, issue TRL Report 589: 1–65.

Mara 1996 *{published data only}*
Mara MK, Davies RB, Frith WJ. Evaluation of the effect of compulsory breath testing and speed cameras in New Zealand. Combined 18th ARRB Transport Research Conference. Sept 2–6, 1996:Part 5, 269-82.

Oei 1995 *{published data only}*
Oei H, Goldenbeld C. Evaluation of the enforcement of speed on 80 km/h and 100 km/h roads in the province of Friesland [Evaluatie van het toezicht op snelheid op 80 –en 100 km/uur–wegen in Friesland]. Stichting Wetenschappelijk Onderzoek Verkeersveiligheid SWOV 1995, issue R–95–24:3–59.

Oregon 1997 *{published data only}*
Cities of Beaverton, Portland. Oregon. Photo radar demonstration project. http://www.portlandonline.com/1997:1–12.

Pigman 1989 *{published data only}*
Pigman JG, Agent KR, Deacon JA, Kryscio RJ. Evaluation of unmanned radar installations. *Transportation Research Record* 1989; **1244**:7–16.

Rooijers 1991 *{published data only}*
Rooijers AJ, De Bruin RA. Selective enforcement of speeding behaviour in built-up areas. Institute for Road Safety Research SWOV, Netherlands 1991, issue C 229:51–4.

Sisiopiku *{published data only}*
Sisiopiku VP, Patel H. Study of the impact of police enforcement on motorists' speeds. *Transportation Research Board* 1999;**1693**:31–6. [: ISBN 0309071178,ISSN 03611981, Project no 1693 –007]

Stradling 2002 *{published data only}*
Stradling S, Campbell M. The effects of safety cameras on drivers. RoSPA: 67th Road Safety Congress 'Safer Driving - The Road to Success'. 4–6th March 2002:1–11.

Swali 1993 *{published data only}*
Swali L. The effect of speed cameras in West London. Traffic management and road safety, PTRC seminar, Manchester. PTRC Education and Research Services Ltd, 1993.

Teed 1993 *{published data only}*
Teed N, Lund AK. The effect of laser speed-measuring devices on speed limit law enforcement in Charleston, South Carolina. *Accident Analysis and Prevention* 1993;**25**(4):459–63.

Werner 2002 *{published data only}*
Werner J. Dutch variable speed pilot test employs photo speed enforcement. ITS Cooperative Deployment Network. National Associations working group for ITS, 2002:1–2. [: 00934671]

References to studies awaiting assessment

Anderson 2001 *{published data only}*
Anderson R, Edgar AW. Mobile speed cameras in the ACT: Slashing speeds and cutting crashes. Road Safety Research, Policing and Education Conference. 2001.

Carseldine 2003 *{published data only}*
Carseldine D. Fixed digital speed cameras in NSW: Impacts on vehicle speeds and crashes. Roads and Traffic Authority, New South Wales (NSW) Australia 2003:1–7.

Additional references

ATSB 2003
Australian Transport Safety Bureau. Database Statistics. Requested from the ATSB database 2003.

Carsten 2002
Carsten O. European Research on ISA: Where are we now and what remains to be done. Proceedings: ICTCT workshop Nagoya, Japan. 2002:1–14.

Chen 2000
Chen G, Wilson J, Meckle W, Cooper P. Evaluation of photo radar program in British Columbia. *Accident Analysis and Prevention* 2000;**32**:517–26.

Cook 1979
Cook TD, Campbell DT. Quasi-Experimentation: Design & Analysis Issues for Field Settings. Houghton Mifflin Company, USA 1979.

EPOC
Cochrane Effective Practice and Organisation of Care Review Group (EPOC). The Data Collection Checklist. EPOC, Institute of Population Health, University of Ottawa, 1 Stewert St, Ottawa, Ontario, Canada K1N 6N5 http://www.epoc.uottawa.ca.

Hauer 1997
Hauer E. Observational Before-After Studies in Road Safety. Pergamon. Oxford 1997.

Keall 2001
Keall MD, Povey LJ, Frith WJ. The relative effectiveness of a hidden versus a visible speed camera programme. *Accident Analysis and Prevention* 2001;**33**:277–84.

Krug 2002
Krug E (Ed). Injury a leading cause of the global burden of disease. Geneva, World Health Organisation (WHO) 2002.

Murray 1997
Murray CJL, Lopez AD. Alternative projections of mortality and disability by cause 1990 -2020: Global burden of disease study. *Lancet* 1997;**349**:1498–504.

Peden 2004
Peden M, Scurfield R, Sleet D, Mohan D, et al.World report on road traffic injury prevention. Geneva, World Health Organisation (WHO) 2004.

Pilkington 2002
Pilkington P. Increasing visibility of speed cameras might increase deaths and injuries on roads. *BMJ* 2002;**324**:1153.

Pilkington 2005
Pilkington P, Kinra S. Effectiveness of speed cameras in preventing road traffic collisions and related casualties: systematic review. *BMJ* 2005;**330**:331–4.

US TRB 1998
Transportation Research Board. Managing Speed: Review of current practice for setting and enforcing speed limits. Special report 254. http://gulliver.trb.org/publicaitons/sr/sr254.pdf 1998; Vol. Washington DC.

Zaal 1994
Zaal D. Traffic law enforcement: A Review of the Literature. Monash Accident Research Centre (MUARC) Victoria, Australia 1994; Vol. Report No 53:1–200.

* *Indicates the major publication for the study*

CHARACTERISTICS OF STUDIES

Characteristics of included studies *[ordered by study ID]*

AU NSW 1

Methods	Controlled before-after study. Study period from February 1982 for nine weeks. Speed measurement before, during and after enforcement. Two experimental and one control site.
Participants	Eastern suburbs of Sydney, two lane sub-arterials carrying less than 10,000 vehicles/day but carrying commuter traffic. Streets had 60 km/h speed limits.
Interventions	Police presence in stationary car with radar units at both sites, overt at site 1 and hidden from view at the primary 2nd site. Primary point for speed measurement was 300m post police car and secondary point was 200m before police car, at both sites. Enforcement periods were 8.00am to 9.00am and 2.00pm to 3.00pm. Speed surveys were conducted between 8.00am to 9.30am and 2.00pm to 3.30pm, i.e. for 30 minutes after police had left the site.
Outcomes	Effects of enforcement on traffic speeds on urban roads including halo effects. Proportion of vehicles exceeding the speed limit reduced by about 70% when police present and with commuter traffic a time halo effect lasted at least two days.
Notes	Perception of enforcement only. Outcomes measured - proportions of speeders over 60 km/h and 70 km/h. Control site characteristics - also had a 60 km/h limit and located in the eastern suburbs. No other characteristics described.

AU NSW 2

Methods	Controlled before-after study. ’Before’ crash data January 1985 to November 1986. ’After’ crash data January to November 1987. Only 100 km/h speed limit areas within sites used for crash data. Study period for speed data, December 1986 to March 1987. Speed data points - before and again at three and six weeks after start of aerial enforcement. Two sites were chosen for detailed examination. Speed was measured at four locations (upstream and downstream as well as within marked area) for each site on four days - one day before aerial enforcement, during, one day after and on the fourth day after operation started. 14 experimental and 14 control sites used for crash analyses and 10 experimental and 5 control sites used for speed analyses.
Participants	This study reports an investigation of crashes at nine of 24 rural highway sites in New South Wales that came into operation in December 1986. The nine experimental grids provided 14 experimental sites which were matched by 14 control sites. For speed, 10 experimental sites were chosen and five matched control sites were selected. All sites were within a 100 km/h speed limit zones except for two experimental sites and one control site, which were in 110 km/h zones.
Interventions	Aerial surveillance involving a police aircraft flying at 500 to 700m over a series of marked grids on roadways. Speeds were calculated by an observer using a stopwatch and radar unit who timed vehicles over set distances and radioed ’speeder information’ to ground crew police in hidden patrol car who then issued speeders with traffic infringement

AU NSW 2 (*Continued*)

	notices.
Outcomes	Reports crash and speed outcomes. A 23% reduction in crashes at experimental sites during the day and a 21% reduction at other times relative to trends in crashes at control sites. Reduction in overall mean speed only about 2-3 km/h. similar reduction found at controls sites. While aerial surveillance was operating speed reductions extending up to 14 kms downstream from the marked zone was evident and some reduction was evident for the day after.
Notes	Experimental (E) and control (C) sites were matched in terms of suitability for aerial surveillance, on average annual daily traffic (E sites averaged 7,200 vehicles per day while C sites averaged 8,000), length (E sites averaged 14.3 km while C sites averaged 16.6 km), road classification (all sites were 2 or 3 lane rural highways) and speed limit (all had a predominant 100 km/h limit). Possibility of regression to mean regarding the number of crashes at experimental versus control site discussed. When comparing both crash and speed outcomes, it is seen if any speed reduction was evident, however the speed study was conducted over a short six week period and it was seen from the 'crash study' that crash effects were only evident after the program had been in operation a few months.

AU QLD 1

Methods	Quasi-experimental with comparison group, using trend analysis. Study period 1986 to 1996. Experimental sites have been compared to sites not influenced by the enforcement program. 'Before' data from 1986. Progressive introduction of enforcement program from 1992. 'After' data to end of June 1996.
Participants	Statewide Queensland. State stratified into seven police regions each of which is further divided into urban and rural areas (making 14 strata in total). These areas are further divided into police districts that cover groups of police divisions. Each individual police division (279 police divisions by close of study) select a road segment, typically 40 sites within it, for enforcement. Speed zones were defined as greater than 60 km/h and equal or less than 60 km/h.
Interventions	Stationary marked police car at a randomly selected site for two hours of enforcement between 6.00am and midnight.
Outcomes	Effects of program on crash frequency and crash severity in Queensland (four crash severity levels). Crash data from five years before intervention. All other outcome data come from: 1. crashes enforced time in enforced area 2. crashes un-enforced time in enforced area 3. crashes enforced time in un-enforced area 4. crashes un-enforced time in un-enforced area Estimated 31% reduction in fatal crashes. Overall a significant 11% reduction in total crashes outside of metropolitan Brisbane.
Notes	This study of Random Road Watch (RRW) is a traffic policing program in operation in Queensland, Australia. It differs from other road safety enforcement programs in that an explicit resource management technique is used which randomly schedules low levels of police enforcement with the intention of providing long-term widespread coverage of a road network. Outcome crash data from police records rather than an automated system. Characteristics of comparison sites given.

AU QLD 2

Methods	Controlled before-after study. Study conducted from May 1997 to end of June 2001. 'Before' data from January 1992 to December 1996. Experimental areas within 6km of camera site dissected by three (0 to <2km, 2 to <4 km, 4 to <6km). Matched control areas outside the 6 km "zones of influence". Crash data from January 1992 to June 2001.
Participants	Sites throughout Queensland that had undergone a speed limit review and had a high speed related injurious crash history. 500 sites in 1997 to over 2,500 sites by June 2001.
Interventions	Mobile overt cameras used which were randomly deployed and operated for up to six hours per day at one or more of three sites per day.
Outcomes	Localised crash effects were measured. A 45% reduction in fatal crashes in areas within 2 km of camera sites. Corresponding reductions of 31%, 39%, 19% and 21% were estimated for hospitalisation, medically treated, other injury and non-injury crashes respectively. This equates to an annual crash reduction of 110 fatal, 1100 hospitalisation, 2200 medically treated, 500 other injury and 1600 non-injury crashes in Queensland.
Notes	Control sites matched by level of urbanisation, similarity of police region and similarity of Random Road Watch (RRW) program. Study limitation in that crash to nearest camera site didn't mean that there was a camera there at the time.

AU South Australia

Methods	Controlled before-after study. Study conducted from November 1991 to February 1993. 'Before' speed data (two data points) from November 1991 to end of February 1991. 'After' speed data (measurement x 4) from March 1992 to February 1993. Ten experimental sites and two control sites.
Participants	Residential area with ten deployment sites (streets) in city of Unley, South Australia approximately 4km from north to south and 700m from east to west.
Interventions	Overt mobile speed camera, random deployment to enforce a new 40 km speed limit to local residential streets. Low intensity enforcement. (1.5 hours per fortnight)began March 1992. High intensity enforcement began October 1992 (at least 1.5 hours x 5 per fortnight). Operational conditions for control sites not clearly described.
Outcomes	Median traffic speeds reduced sharply by 5 km/h on experimental roads after program launch and reduced very little thereafter despite intensified enforcement however improvement sustained over the whole trial period whereas control sites showed no change or slight increases in speed.
Notes	Controls were matched on the basis of width, length and traffic flow. Assumption that speed limit same for experimental and control streets as they were adjacent. Speed data on all vehicles passing each study site (experimental and control) was collected for one full week during

AU South Australia (*Continued*)

	each survey. Both speed and traffic volumes were recorded using Golden river classifiers with amphometer tubes as sensors. This equipment was capable of storing a complete weeks data, it achieved this by 'binning' data i.e. instead of recording each vehicle's speed it simply recorded the passage of a vehicle in a particular speed category which imposed some restrictions on data analysis

AU Tasmania

Methods	Controlled before-after study. Total study length was two years between December 1984 and December 1986. Continuous speed measurement for periods of three days to two weeks in one month in 1984, 1985, 1986. Crash data from 1979 to 1986. Three experimental sites and one control site plus all other Tasmanian roads also used for crash comparisons.
Participants	Three road locations each 12 km to 16km in length divided into approximately 1km sections. Road type - contiguous sections of rural highway or main road where speed limit was 110km/h. Control was similar road within 10km of experimental sites.
Interventions	Overt stationary police vehicles for 4 by 2 hours periods 7 days per week, random scheduling of road sections, 5 site visits per week for 2 weeks then 2 to 3 site visits thereafter.
Outcomes	A significant decrease in mean speeds by average of 3.6 km/h (P=0.01) compared to before, but reduction only maintained during enforcement showing no time halo effect. A significant 58% reduction in serious injury crashes (admitted to hospital or fatal) compared to previous crash history and crash occurrence on other rural roads. In non-enforced times of day a 33% increase in major injury crashes was seen.
Notes	Characteristics of trial site lead it to be classified 90 km/h, whilst control site was 110km/h, thus lower mean speeds at trial site. This was taken into account in the analysis and discussion.

AU VIC 1

Methods	Interrupted time series design with a control arm for phase 1 and phase 2 of a 5-phase study. Total study period 1983 to 1993.
Participants	Statewide Victoria inclusive of rural and metropolitan areas. Metropolitan areas defined as those areas within specified police districts.
Interventions	Interventions were: 1. mobile radar devices 2. hand held laser speed detector devices 3. speed cameras - progressive introduction of 54 speed cameras between December 1989 to January 1991 with 4 distinct points (T1a,T1 b, T2a, T2b). Initially speed cameras were overt then from 1990, largely covert.
Outcomes	Phase 1 - General effects; effect of speed camera program on crash rate and severity covering first 12 month post intervention period, December 1989 to December 1990. Phase 2 - Impact of program mechanisms i.e. number of traffic infringement notices (TINs), hours of speed camera operations, amount of paid TV publicity, demerit points in relation to injury crash incidence and severity during low

	alcohol times of the week across the first two year post intervention period. Phase 3 - Areas and times of operation of speed camera program affecting frequency and severity of all types of injury crashes during both high and low alcohol hours in Melbourne covering 18 months of program (July 1, 1990 to December 31, 1991). Phase 4 - Program effects on speeds, including influence of publicity from sample sites between November 1989 to June 1991 (five measurements)and from continuous sites November 1989 to January 1992 (monthly measurements for one week duration). Phase 5 - builds on phase 3 by analysing localised effects of program in; a) rural towns and rural highways B) metropolitan Melbourne. this phase covers an additional 24 months of program (July 1990 to December 1993). Phase 1 and 3 - Injury crash frequency reduced by about 30% on 60km/h Melbourne city, A reduction of about 20% in rural 60km/h zones and a reduction of 14% in rural 100km/h zones.
Notes	Control area for phase 1 and 2 was another State, New South Wales, as no suitable control in the State of Victoria, thus some limitations, however most comparable in terms of urbanisation, economic activity, population size, vehicle kms travelled and unemployment rate. Controlled for random breath test (RBT) program in operation, by restricting relevant crash analysis to low alcohol hours.

AU VIC 2

Methods	Controlled before-after study. Study period May 2000 to October 2000, a period of about 20 weeks. ’Before’ period 8th May 2000 to 21st May 2000. ’After’ period 18th October to 31st October 2000. 1 experimental and 1 control site.
Participants	Domain tunnel Melbourne, three-lane urban road with 80 km/h speed limit. The control was a second three-lane road upstream of the tunnel.
Interventions	Fixed position speed camera operating continuously.
Outcomes	Net 3.4% speed reduction (after consideration of changes in average speeds that occurred at control site during the same before-after periods). Change in proportion of drivers exceeding 50km/h, 90km/h and 110km/h. Estimated 13% reduction in fatal crashes, 10% reduction in serious injury and 7% reduction in overall injuries. Net 3.4% speed reduction (after consideration of changes in average speeds that occurred at control site during the same before-after periods). Change in proportion of drivers exceeding 50km/h, 90km/h and 110km/h. Estimated 13% reduction in fatal crashes.
Notes	The ’before’ period is when the cameras are in the tunnel but no infringement notices are being issued, therefore arguably not truly independent as not everyone would know the cameras weren’t operational. This would probably have the effect of slowing down speed in the before period making differences smaller.

AU VIC 3

Methods	Controlled before-after study. Study period 1992 to 1997. ’Before’ crash data July 1992 to June 1994. ’After’ crash data July 1995 to June 1997. Experimental sites were undivided roads in 100km/h speed zones. Control sites were defined as undivided roads in 100km/h speed zones when mobile radar was not present within four days prior to a crash.
Participants	Mainly rural Victoria with some enforcement (about 10% of total mobile enforcement activity) in the outer Melbourne police districts of Victoria.
Interventions	Interventions were overt patrol cars using mobile radar, covert patrol cars using mobile radar, and mixed overt/covert cars using mobile radar. Most operations were overt. Intervention events were divided into Period A (July 1995 to June 1996) when 48 radars were in operation and Period B (July 1996 to June 1997) when 73 radars were in operation and Period A+B (July 1995 to June 1997) when up to 73 radars were in operation.
Outcomes	Outcomes were reductions in injury crashes within four days of camera enforcement and during July 1995 to July 1997. A net reduction of 71.3% (P=0.064) was found for crashes occurring on the same day or up to four days after the enforcement was present. The effect was strongest (a net 73.9% reduction (P=0.045)) on the day when a mix of overt/covert enforcement was in use.
Notes	The study compared crashes that occurred during the period of mobile radar enforcement with the period when there was no mobile radar enforcement, however the authors state that other types of enforcement e.g. hand held radars may have been operating on the same roads during the pre-period that may not have been accounted for by changes in the control crashes. Calculation of net percentage change between control and experimental groups was designed to control for other confounders. The analysis assumed that crashes were exclusively influenced by the most recent mobile radar enforcement present in a particular region. This most recent enforcement was considered to override any enforcement that occurred one to four days earlier, which also may have influenced crash rate. Given that a four day residual effect on crashes was found in the analysis, the study authors acknowledge the most recent enforcement may not necessarily have been the most important in influencing crash frequency.

CA British Columbia

Methods	Controlled before-after study. Study period January 1991 to July 1997. ’Before’ speed data September 1995 to February 1996. ’After’ speed data August 1996 to November 1996 at monitoring sites, and from August 1996 to July 1997 at photo deployment sites. ’Before’ crash data from January 1991 to February 1996 and ’after’ crash data, August 1996 to July 1997.
Participants	Province-wide throughout British Columbia. Controls consisted of 19 sites on selected highways and streets where radar was not operating. Data was collected by induction loops from these sites between September 1995 and November 1996. Eight days of speed data collected every month.
Interventions	30 mobile speed cameras using unmarked mini-vans. 30,000 hours of operation recorded in first year with about 250,000 tickets issued. Intervention period was August 1996 to July 1997.

CA British Columbia (*Continued*)

Outcomes	Proportion of speeding vehicles in May 1996 (before) at photo radar sites was 66%. By July 1997(after) it was about 35%. At control sites speeding vehicles in September 1995 was ~73%. In Nov 1996 it was ~61%. Approximately 25% reduction in crashes to that expected. A significant 11% reduction in number of victims with an average decrease of 139 daytime traffic crashes requiring an ambulance. A 17% reduction in daytime crash fatalities.
Notes	Selection criteria for control sites included distance to traffic control devices, non-congestion, speed limits but how well they matched experimental sites not discussed. Controlled for vehicle miles travelled (motor fuel sales) state of the economy (unemployment rate) and amount of drink driving (draught beer sales) in modelling. Later beer sales and unemployment rate excluded from time series models.

CA Toronto

Methods	Controlled before-after study. Study period October 1979 to December 1979; five week study. Data collection by 2.5 hours per day on weekdays over the five consecutive weeks at four experimental and four control sites.
Participants	Locations were semi-rural, two-lane roads west of metropolitan Toronto.
Interventions	Four experiments are described, each experiment consisted of measuring speed of vehicles before, during and after enforcement took place. Each of the four experimental sites had an 'upstream' enforcement and a 'downstream' measurement site (latter was 1 to 2.5km from the site of enforcement). In experiment 1 the police van was visible in advance. In experiment 2 to 4 the police vehicle was visible to the driver only 200m to 300m before passing the speed sensors. The four experiments differed in the number of days of enforcement (see results tables).
Outcomes	For a single application of enforcement a 'time halo' lasted for up to three days. When enforcement was applied for five consecutive days, a time halo of at least six days from the last day of enforcement was found. When enforcement was in place the average speed of the traffic stream was reduced at the site of enforcement, upstream and downstream of it. At the site of speed limit enforcement, the average speed of the traffic stream was around the posted speed limit. This reduction in average speed decays exponentially with distance downstream.
Notes	Study authors state control sites were selected to take "account of the effect of weather, day of week and other factors". They also state concurrent measurements were done on control roads, otherwise no further description of control characteristics were given or how close control sites were to experiment sites. Little information only on 'before' data.

CA Vancouver

Methods	Controlled before-after study. Study period August 1995 to March 1998. Introduction of photo radar program April 1996. Enforcement phase started August 2nd 1996. Speed data from August 1995 to April 1998. Two years ’before’ crash data from April 1994 to March 1996. Two years ’after’ data from April 1996 to March 1998.
Participants	One 22km four-lane highway corridor in rural/semi-rural countryside in province of British Columbia. Controls consisted of other selected highways and streets where radar was not operating, used for crash comparisons. No true control for speed (see notes).
Interventions	12 individual photo radar locations along corridor (not active at the same time). Study corridor was divided into photo-radar influence (PRP) locations and non-photo radar influence (non-PRP) locations. A PRP location was designated as a 2km section of highway, 1 km in each direction from the photo radar enforcement. The non-PRP locations varied in length from 0.4 to 5.9km, depending on the proximity to the adjacent treatment locations.
Outcomes	2.8km/h reduction in mean speed at monitoring site 2km from treatment area. A 14% (+/-11%) reduction in expected crashes at PRP locations, a 19% (+/-10%) reduction at non-PRP locations and a 16% (+/-7%) reduction along the study corridor as a whole.
Notes	Site specific study using data from the same period as the province wide study. PRP and non PRP areas cannot be considered independent of each other as in some cases the non -influence areas only 400m long and are in between PRP areas. Results suggest this lack of independence too. Speed data was captured at PRP locations by the photo radar device but only when radar operating. Speed captured at the monitoring site (2km south of the nearest photo radar) on a 24 hour basis collected over an 8-day period every month by induction loop for both the before and after period. Controlled for regression to mean.

DE Germany

Methods	Controlled before-after study. 12 year total study period 1970 to 1983. Two ’before’ speed measurements in 1971 and 1972. In May 1973 radar installed . Eight ’after’ speed measurements between 1974 and 1983. 12 years ’before’ crash data and 9 years ’after’ data, between 1960 and 1982.
Participants	One interstate road (A3) on the autobahn at Elzer mountain in Germany. The rest of the same autobahn used as the comparison. Speed limits of 100km/h for car lanes and 40km/h for truck lane.
Interventions	Overt speed cameras by three in fixed position on bridges (corresponding to three lanes on autobahn) operating continuously. Police surveillance also in operation several times per year. Speed limits of 100km/hr for cars and 40km/hr for trucks.
Outcomes	In 1971 before enforcement the median speed was 137km/h and 122km /h in the left and middle car lane. By 1981 the median speed was 97km/h and 94km/h in these lanes. The 85th percentile speed reduced from 150km/h and 135km/h in the left and middle lanes in 1971 to 108km/h and 98 km/h respectively by 1981. Reductions in median and 85th percentile speed also occurred in the truck lane, with median speed down from 55km/h to 32km/h between 1971 and 1981 and 85th percentile speed down from 80km/h to 41km/h in the same timeframe.

DE Germany (*Continued)*

	Personal injury crash frequency reduced by a ratio of 18:1 between 1971 and 1981. Reduction in crashes from 200 in 1970-1971 to 84 in 1973 to about 27 in 1980 for the most dangerous downgrade section. Fatalities reduced from eight in 1970 to 1971 to three in 1973 to an average of one per year since 1976. Personal injury crashes reduced from about 82 per year in 1970 to 1971 to 27 in 1973 to about seven per year since 1976.
Notes	Speed measures in the before period relate to speeds before a) introduction of speed limits and b) introduction of speed cameras. Summary statistics not given. Not clear if the analyses controlled for any known or potential confounders.

DK Denmark

Methods	Controlled before-after study. Study period April 1994 to March 2001. Pilot program ran from April 1999 to April 2000. Three years crash data for 'before' period April 1994 to March 1997, and two years 'after' data April 1999 to March 2001.
Participants	Twenty experimental sites compared with ten control sites involving the cities of Copenhagen, Odense and Svendberg in Denmark.
Interventions	Mobile speed cameras in operation two hours on average at varied sites on a daily basis. 105,000 cases of speeding were recorded during the one year project.
Outcomes	During pilot program an overall 2.4 km/ h reduction in mean speed with only small differences between the three cities. A 10.4% reduction in % of drivers exceeding speed limit and a 4.5% reduction in those exceeding the speed limit by 10km. A 22% reduction in injurious crashes in first year and 20% in second year post intervention compared to before.
Notes	Characteristics of control sites not described.

FI Finland

Methods	Controlled before-after study. Study period April 1990 to December 1993. 'Before' period April 1990 to March 1992. 'After' period April 1992 to March 1994.
Participants	Experimental area was a 50km length of a two-lane stretch of highway No. 1, leading west of Helsinki. Control area was Highway No 6 leading east of Helsinki. Speed limits of 80km/h and 100 km/h on study sites.
Interventions	12 fixed camera poles distanced between 1.5km and 7km. One direction of road monitored and camera rotated randomly between poles. Duration of surveillance 8 to 36 hours, involving 8065 hours of operation between April 1st 1992 and December 31st 1993.

FI Finland (*Continued)*

Outcomes	On 80 km/h sections an 8% reduction of speeding vehicles seen on experimental sites compared to control sites in year one, with a further 2% decrease in year two. On 100km/h stretches a 5% reduction in number of speeders was seen in year one, with a further 2% reduction in year two. Distance halo of 3km upstream and 2km downstream. A non-significant 19% reduction in crashes (not defined) compared to controls.
Notes	Crash analysis is limited as only a short follow-up period for crash data (April 1992 to December 1993). Control site characteristics apart from road type and speed limits not given. Study doesn't account for any other potential confounders either.

GB Cambridge

Methods	Interrupted time series design. Study period 1990 to 2002.
Participants	Cambridgeshire. Injury crash data collected over a 12 year period 1990-2002 for camera and non-camera sites. Speed data from before and after installation of cameras as well as limited data from surrounding areas during the same period plus rest of network comparison. At least one year after period data.
Interventions	Progressive introduction of speed cameras from 1991. 49 overt fixed camera sites in Cambridgeshire.
Outcomes	Mean crash count per month at camera sites weighted by severity. Estimates in crash count for different distances from camera sites. A 45.74% reduction in weighted injury crashes within 250m from camera sites (total monthly before count of 23.4 compared to total monthly after count of 12.7) with lesser but still significant decreases observed in the wider surrounding areas such as a 20.86% reduction inside a 2000m radius from the camera.
Notes	Extension of earlier study. Hypothecation introduced in 2000. Controlled for regression to the mean and for season and trends.

GB Nationwide

Methods	Interrupted time series design. Study period 1997 to 2003. 'Before' and 'after' crash data for over 2,300 sites in 24 partnership areas. 11,600 speed surveys taken over three years. 'After' speed data between April 2002 to April 2003.
Participants	Multiple areas throughout UK.
Interventions	A mixture of both fixed and overt mobile speed cameras.

GB Nationwide (*Continued)*

Outcomes	Outcomes measured; killed and seriously injured (KSIs), personal injury crashes (PICs). Average speeds and proportion over speed limits. Reduction in long-term average speed of around 8% for fixed cameras sites in rural areas and a 15% reduction for fixed cameras sites in urban areas. About 40% fewer KSIs and 33% fewer PICs at camera sites. A 40% reduction in fatalities (over 100 fewer deaths). A reduction of 23% in PICs and 35% in KSIs for pedestrians.
Notes	No significant difference was found between fixed, red light and digital cameras hence were grouped together in the analysis as fixed cameras. Controlled for seasonal effects and long term trend by using data from areas other than the study and by comparing relative changes in injury crashes to national trends. Did not discuss potential impacts of these factors or did not control for regression to the mean.

GB South Wales

Methods	Controlled before-after study. Study period 1996 to 2000. Average length of time before intervention was 38 months and average follow-up was 17 months. Crash data (with at least one injury) for period 1996 to 2000.
Participants	101 experimental sites, all types of roads in South Wales, UK with matching control sites from Gwent, a neighbouring police force area.
Interventions	Mobile overt speed cameras, 12 cameras by end of 2000.
Outcomes	Rate ratio of injury crashes at intervention and control sites (0-500m route). A reduction of 50% in personal injury crashes which was sustained for two years after the intervention.
Notes	Study compared various methods, circles and routes of various sizes to assess the local effectiveness of mobile speed cameras, and then used the most appropriate method found to examine speed cameras by time after intervention, time of day, speed limit, and type of road user injured. Methodology not clear in this study. Control sites matched for posted speed limit, road class and injury crash history.

GB West London

Methods	Controlled before-after study. Study period 1989 to 1995. Three year 'before' period October 1989 to October 1992. Three year 'after' period October 1992 to October 1995.
Participants	Trunk and non-trunk A class roads in London. Trunk road network was 85km in length. Controls were comparable roads in other areas of London with no cameras over the same period.
Interventions	21 fixed speed camera sites at start of project in 1992 (plus 12 red light camera sites) along 10 routes.

GB West London (*Continued)*

Outcomes	Significant reduction in crashes, fatal, serious injuries and lesser injuries per se and in relation to controls. Greatest improvement in higher severity crash outcomes. A reduction of 12.4% for all crashes. Fatal crashes reduced by 69.4% (62 down to 19) relative to before and a significant 55.7% relative to controls. Serious injuries reduced by more than 25% from 4983 to 4375, resulting in a 31% reduction in fatal and serious crashes combined. A reduction of 7.9% in slight injury crashes was reported.
Notes	No separation of effects of red light versus speed cameras. Part control for crash trends. No control for other potential confounders.

HK Hong Kong

Methods	Controlled before-after study. Study period 1998 to 2000, a period of two years. 'Before' period from January 1998 to January 1999. 'After' period from January 1999 to January 2000.
Participants	The experimental group was one 20 km section of highway in Hong Kong divided into 2km sections. The control group was other highway sections in Hong Kong where no speed camera enforcement took place
Interventions	10 fixed speed enforcement systems with two cameras operating continuously on a rotational basis (1:5).
Outcomes	65% reduction in cars travelling in excess of 15 km/h or more over the speed limit. 23% reduction in number of injury crashes compared to before period. In same period there was a 32% increase in number of injury crashes in the control group. Fatal crashes reduced by 66% in the experimental group.
Notes	No detail on characteristics of control group given. Traffic conditions and road type discussed in relation to speed camera operation but not in relation to potential confounding. Statistical methods not adequately shown. Study limitations not discussed.

NL Netherlands

Methods	Controlled before-after study. Main study conducted October 1990 to June 1991 using four experimental and four control roads for phase 1 and phase 2 study. Then phase 3 of Netherlands study conducted in September 1994, with two 'new' control roads for crash data comparisons.
Participants	Four two-lane rural road stretches in four Dutch provinces, 10-17km in length. For phase 3, one road of main study, the N266 in the province of Noord-Brabant used.

NL Netherlands (*Continued*)

Interventions	Unattended fixed overt speed cameras and radar operating randomly off three or four posts installed along each of the four experimental roads from early morning until midnight. Phase 3 continuing from phase 2 also used fixed overt speed cameras and radar.
Outcomes	Speed and crash outcomes. Aggregation of data from the four roads (compared to phase 0) showed a reduction in average speed of 3km/h in phase 1 and 5km/h in phase 2, a reduction in 85 percentile speed of 3km/h in phase 1 and 8km/h in phase 2. A reduction in proportion of speeders from 38.2% to 28% in phase 1 and from 38.2% in phase 1 to 11.4% in phase 2. A reduction of 35% in the total number of crashes for phase 1 and 2 compared to same period three years previously and compared to the control roads (in phase 3). Speed and crash reductions achieved in original study were maintained three years later.
Notes	For phase 3 crash data on experimental road compared to two control roads. No control arm used for speed comparisons.

NO Nationwide

Methods	Controlled before-after study. Study period 1988 to 1993. Mean length of 'before' period was 3.94 years. Mean length of 'after' period was 4.61 years. In no case before or after period less than one year.
Participants	64 road sections each 1-2km long of a total 336.3km road network. All roads rural and two-lane in Norway where automatic speed enforcement had been introduced by 1995. Photo radar enforcement began in 1988. The total number of crashes in the rest of the country in the before and after period was used as a comparison group
Interventions	Fixed overt speed cameras.
Outcomes	A significant reduction of 20% in injury crashes equating to about 62 injury crashes per year on all 64 road sections combined. The decline in the number of injury crashes was related to the level of conformance with official warrants for the use of automatic speed enforcement (see notes). A decline of 26% in injury crashes was found on road sections conforming with both warrants. On road sections not conforming with any of the warrants, injury crashes declined by 5%.
Notes	The warrants refer to crash rate (crashes/vehicle km) and crash density (crashes/km of road). Authors state frequency and duration of interventions unknown thus not possible to study the relationship between the intensity of enforcement and the size of the effects on speed and crashes. No before speed data was available to this study hence camera effects on speed are not assessed in the study. Study controlled for possible confounding due to regression to the mean, changes in traffic volume and general trends in number of crashes.

NO Oslo

Methods	Controlled before-after study. Study period August 1991 to December 1991. 16 week study, two week 'before' period, six weeks enforcement, eight weeks 'after' period. Continuous speed measurement at 12 sites for 16 weeks. One experimental road divided into six sites, one control road divided into six sites.
Participants	One 35km long stretch of semi rural undivided two lane road in Norway with mainly 80km/h speed limits, but some 60km/h speed limits through small more densely populated communities.
Interventions	Five police patrols using stationary speed enforcement with observation units (mainly in unmarked hidden cars) measuring speed by radar or laser gun and 'stop' units using marked visible police cars to enforce. Average nine hours of enforcement daily for six weeks
Outcomes	Reduction in speed relative to the control road. Average speeds were reduced by 0.9-4.8km/h in both speed limit zones and for all times of day. A time halo effect of up to eight weeks was shown. The proportion of speeding drivers was reduced by 10% in both speed limit zones for all hours of day except the morning rush hours 6.00am to 9.00am.
Notes	The control road was close enough to have same weather conditions but the road ran through different communities hence migration of traffic not expected.

NZ Christchurch

Methods	Controlled before-after study. Study period 1988 to 1997. Compared four years 'before' (1989 to 1992) data with four years 'after' data (1994 to 1997).
Participants	City of Christchurch, New Zealand. Controls were matched non-camera sites in Christchurch.
Interventions	Progressive introduction of fixed overt speed cameras in 24 speed camera zones.
Outcomes	Measures were average speeds and all crashes and serious injury crashes. The average difference between the 85th percentile and mean for the four years before and four years after was only 0.8km/h. Reduction of 9.17% in crashes and 32.4% in serious injury compared to New Zealand overall.
Notes	Controlled for crash trends and changes in traffic volume.

NZ Nationwide

Methods	Interrupted time series design with a comparison. area involving a primary and secondary study. For primary study the study period was from June 1997 to June 1999. Aggregated monthly crash data from November 1993 to July 1999. Speed data from July 1995 to July 1999. Secondary study for period 1996 to 2002.
Participants	The experimental area was the Midland Police Region of New Zealand, consisting of all 100km/h open roads in existing speed camera areas, 100km/h open roads generally, and 100km/h open roads with existing speed cameras plus new covert speed cameras. The control areas were 100km/h open roads in existing speed camera areas and 100 km/h roads generally, in the rest of New Zealand. For secondary study, all New Zealand 100km/h open roads excluding the Midland Police region where the primary study took place.
Interventions	For primary study, an increase in enforcement where covert cameras were added to the 100km/h roads which already had an overt speed camera program in place. For the second study, overt speed cameras used within designated speed camera sites up to 5km in length. On open road most cameras were mobile operated from the rear of a (usually unmarked) police vehicle.
Outcomes	2.3km/h reduction in mean speeds (P=0.05) at speed camera sites on open roads compared to rest of the country in the first year. Injury crash outcomes in experimental areas compared to control areas controlling for season and trend. A net reduction of 11% in crashes and 19% in injuries on open roads across the region was found, associated with the hidden cameras over and above the effects of the existing speed camera program. For the second study, the main outcome was an estimated injury crash reduction of 12% associated with a 1km/h reduction in mean open road speed during low alcohol hours. Estimated reductions in mean speeds of 0.7% and 0.8% were found, associated with each increase of 10,000 speed camera infringements and 10,000 other speed infringements respectively. Higher reductions of 1.1% and 1.6% were found in the 85th percentile speeds.
Notes	This study updates an earlier publication. Speed cameras were introduced to New Zealand in 1993. This study involved an increase in camera operation and enforcement. Generally the cameras in control areas were overt. Control areas were matched for level of road safety advertising, quality of roads, road use, vehicle speeds prior to the trial and unemployment rates in the regions concerned. Enforcement tolerance of 10km/h over the speed limit used however speed measures involved speed limit and number of kms above the speed limit (in 5km/h bands).

US Washington DC

Methods	Controlled before-after study. Study period June 2000 to February 2002. Approximately three months ’before’ period June to August 2000. About two months ’after’ period January to February 2002. Enforcement commenced August 1st 2001.
Participants	Seven experimental sites and eight control sites. Combination of residential streets, school and work zones and arterial roads in seven police patrol districts in Baltimore.

US Washington DC (*Continued)*

Interventions	Five speed cameras in unmarked police cars deployed twice per week at each zone between 6.00am and 10.00pm, Monday to Saturday.
Outcomes	Mean speeds at experimental sites reduced by a significant 14% compared to control sites. The proportion of vehicles exceeding the speed limit by more than 10mph decreased 82%.
Notes	Characteristics of control sites not clearly described.

Characteristics of excluded studies *[ordered by study ID]*

Al Maseid 1997	Controlled study but no 'before' data period for comparison.
Ali 1997	Uncontrolled before-after study.
Bellotti 2001	Uncontrolled before-after study.
Benekohal 1993	Controlled before-after study however, no enforcement and data collection only averaged one hour.
Bourne 1993	Uncontrolled before-after study.
Brimson 2002	Controlled before-after study however initial control sites were discarded during study when it was found that the comparison was not going to be statistically reliable and other control sites were chosen. Also it was not possible to separate out the effects of red light cameras versus speed cameras in this study.
Cameron 2003	The main focus was the analyses of any interaction between speed camera enforcement and road safety mass media publicity.
Casey 1993	Controlled before-after study however, the main outcome focus was effects of variable message signs rather than enforcement.
Chin 1999	Uncontrolled before-after study.
Diamantopoulou 1998	Study was developed further in a later publication which was included in this review.
Ha 2003	Uncontrolled before-after study.
Hakkert 2000	Study design and methodology unclear.
Holland 1996	Uncontrolled before-after study.
Hook 1995	Uncontrolled before-after study.

(*Continued)*

Hooke 1996	Uncontrolled before-after study. Methodology unclear. Main focus was cost benefit analyses rather than effects on road trauma per se.
Johannessen 2002	Uncontrolled before-after study.
Lund 1977	Uncontrolled before-after study.
Mackie 2003	Controlled before-after study, however unable to differentiate between effects of multiple road safety measures implemented concurrently. This study was a preliminary report by Bellotti P (TRL) which was later followed by the final report by Mackie et al (TRL) already listed in the excluded studies table.
Mara 1996	Uncontrolled before-after study.
Oei 1995	Uncontrolled before-after study.
Oregon 1997	Controlled before-after study however, insufficient useable data and no further information available from source.
Pigman 1989	Uncontrolled before-after study.
Rooijers 1991	Uncontrolled before-after study.
Sisiopiku	Uncontrolled before-after study.
Stradling 2002	Uncontrolled before-after study.
Swali 1993	A preliminary analysis only, whereas, the main study is included in this review.
Teed 1993	Uncontrolled before-after study.
Werner 2002	No control arm used plus main focus of study was the evaluation of the effect of a variable maximum speed limit on roadway capacity, rather than the outcomes of interest in this review, speeding and injurious crashes per se.

DATA AND ANALYSES

This review has no analyses.

APPENDICES

Appendix 1. Search strategy

As search strategies are specific to databases, we modified the search strategies combining key words with their related thesaurus terms for all the possibilities related to interventions, outcomes and study design (see Table 6 for list of key words). We searched MEDLINE, EMBASE and TRANSPORT using the following strategies:

Table 6. Search Terms

Interventions	Outcomes	Study design
Speed camera(s)	Vehicle speed	Randomised controlled trial
Safety camera(s)	Car speed	Controlled trial
Photoradar	Time and distance halos	Before and after study
Radar gun/Laser	Road traffic safety	Time series design
Speed control	Road traffic crashes	Impact study
Speed enforcement	Road traffic accidents	Intervention study
Police enforcement	Road traffic collisions	Comparative study
Speed limit(s)	Road traffic violations	Field study
Speed measurement	Road injuries and deaths	Observational study
Speed control	Road fatalities	
Road accident prevention		
Traffic accident prevention		

MEDLINE and **EMBASE**

#1 speed near camera*

#2 safety near camera*

#3 photo near radar

#4 radar near gun

#5 automat* near enforc*

#6 #1 or #2 or #3 or #4 or #5

#7 speed* near enforc*

#8 speed* near halo

#9 road near speed* near limit*

#10 traffic near speed* near limit*

#11 # 6 or #7 or #8 or #9 or #10

#12 stud* or trial

#13 # 11 and #12

TRANSPORT

1. police* or speed* or vehicle* or motor vehicle* or automobile*

2. enforce* or detect* or radar* or camera* or laser* or limit*

3. #1 near #2

4. accident* or colli* or fatal* or injur* or crash* or speed*

5. reduc* or prevent* or safe* or deter* or aver* or avoid* or control* or prohib* or stop* or cut* or curtail* or decreas* or limit* or minim* or moderat*

6. #4 near #5

7. #3 and #6

8. before-after

9. before-and-after

10. before-and-after-studies

11. before-and-after-study

12. #8 or #9 or #10 or #11

13. controlled-trial

14. controlled-trials

15. #13 or #14

16. placebo-controlled

17. placebo -effekt

18. placebo-kontrollierten

19. placebo-konzepts

20. placebo-washout

21. placebogruppe

22. placebokontrollierten

23. #16 or #17 or #18 or #19 or #20 or #21 or #22

24. double-blind

25. single-blind

26. #24 or # 25

27. randomisation

28. randomization-

29. randomize

30. randomized

31. randomizing

32. randomly

33. # 27 or #28 or #29 or #30 or #31 or #32

34. comparative

35. comparative-analysis

36. #34 or #35

37. impact-studies

38. impact-study

39. impact-study-environment

40. impact studies

41. #37 or #38 or #39 or #40

42. field-studies

43. #12 or #15 or #23 or #26 or #33 or #36 or #41 or #42

44. #7 and #43

Appendix 2. Websites searched

AAA Foundation for Traffic Safety, USA www.aaafoundation.org
Australian College of Road Safety www.acrs.org.au
Australian Road Research Board www.arrb.org.au
Australian Transport Safety Bureau www.atsb.gov.au
Belgisch Instituut voor de Verkeersveiligheid www.bivv.be
British Road Federation www.brf.co.uk
Canada Safety Council www.safety-council.org
Centre for Accident Research and Road Safety; Queensland, Australia www.carrsq.qut.edu.au
Community Research and Development Information Service www.cordis.lu/en/src/
Danish Road Directorate www.vejdirektoratet.dk/roaddirectorate
Danish Transport Research Institute (Danmarks Transport Forskning) www.dtf.dk
Department of Environment, Transport and Regions, UK www.detr.gov.uk
Department of Transport, UK www.dft.gov.uk (Road safety research compendium 2000/2001, 2001/2002, 2002/2003)
Deutscher Verkenrssichereitsrat Road Safety Institute www.dvr.de
European Transport and Safety Council www.etsc.be
Global Road Safety Partnership grsp@ifrc.org
Highway Safety Research Centre, University of North Carolina www.hsrc.unc.edu
Hong Kong Society for Transportation Studies http://home.netvigator.com/~hksts/home.htm
Information and Technology Centres for Transport and Infrastructure) www.crow.nl
Injury Research Centre, Department of Public Health, University of Western Australia www.irc.uwa.edu.au
Institut National de Recherché sur les Transports et leur Securite www.inrets.fr

Institute for Road Safety Research -Netherlands www.swov.nl
Institute of Transport Economics Norway (Transportokonomisk institutt) www.toi.no
Institute of Transportation Engineers www.ite.org
Institute of Transportation Studies, University of California www.its.berkeley.edu/
Institution of Highways and Transportation www.iht.org/
Insurance Institute for Highway Safety (Status Reports) Arlington, VA www.highwaysafety.org
Land Transport Safety Authority New Zealand www.ltsa.govt.nz/roads/crash
Leeds University - Institute of Transport Studies www.leeds.ac.uk/research/index.htm
Liikenneturva - The Central Organisation for Traffic Safety in Finland www.liikenneturva.fi/
London University (Imperial and UCL transport group) www.ic.ac.uk
Monash University Accident Research Centre, Victoria www.general.monash.edu.au/muarc/
National Highway Traffic Safety Administration USA www.nhtsa.dot.gov
National Safety Camera Partnerships www.nationalsafetycameras.co.uk/
New Zealand Institute of Highway Technology www.nziht.co.nz
New Zealand Land Transport Safety Authority www.ltsa.govt.nz
Nordic Road & Transport Research www.vti.se/nordic/
Office of Road Safety for Western Australia www.officeofroadsafety.wa.gov.au
Organisation for Economic Co-operation and Development www.oecd.org
Roads and Traffic Authority, New South Wales. www.rta.nsw.gov.au
Swedish National Road Administration (Vaqverket)
Swedish National Road and Transport Research Institute www.vti.se
Texas Transportation Institute www.tti.tamu.edu/research/
The International Association of Traffic and Safety Science, Tokyo, Japan www.iatssforum.jp/english/contact.html
The Netherlands Transport Research Centre (Adviesdienst Verkeer en Vervoer)
Transport Canada www.tc.gc.gov
Transport Research Laboratory UK www.trl.co.uk
Transport Research, Technical Research Centre of Finland,Espoo www.vtt.fi/transport/
Transportation Research Board USA www.nas.edu/trb/
US Department of Transport -Federal Highways Administration www.fhwa.dot.gov
VicRoads www.vicroads.vic.gov.au
World Health Organisation, Geneva, Switzerland. www.who.int/en/

WHAT'S NEW

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CONTRIBUTIONS OF AUTHORS

Contribution of authors by list of tasks

Protocol development for this systematic review - Willis C, Lybrand S, Bellamy N.

Literature searches - Wilson C, Willis C.

Short-listing of studies -Wilson C.

Selection of studies for inclusion - Wilson C, Willis C.

Development of data extraction form - Wilson C

Development of quality rating tool - Wilson C, Hendrikz JK.

Piloting of quality and data extraction tools - Wilson C, Willis C, Bellamy N.

Data extraction - Wilson C, Willis C, Hendrikz JK.

Quality assessment - Wilson C, Willis C.

Syntheses of results - Wilson C, Hendrikz JK.

Manuscript write-up - Wilson C.

Manuscript review pre-submission - Wilson C, Willis C, Hendrikz JK, Bellamy N.

Project supervisor - Bellamy N.

DECLARATIONS OF INTEREST

None known.

SOURCES OF SUPPORT

Internal sources

- The University of Queensland infrastructure, Australia.

External sources

- Motor Accident Insurance Commission, Australia.

INDEX TERMS

Medical Subject Headings (MeSH)

Accident Prevention [*instrumentation; methods]; Accidents, Traffic [*prevention & control; statistics & numerical data]; Controlled Clinical Trials as Topic; Photography [instrumentation]; Radar [instrumentation]; Safety

MeSH check words

Humans