Helmets for preventing injury in motorcycle riders (Review)

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[Intervention Review]

Helmets for preventing injury in motorcycle riders

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ABSTRACT

Background

Motorcycle crash victims form a high proportion of those killed or injured in road traffic crashes. Injuries to the head, following motorcycle crashes, are a common cause of severe morbidity and mortality. It seems intuitive that helmets should protect against head injuries but it has been argued that motorcycle helmet use decreases rider vision and increases neck injuries. This review will collate the current available evidence on helmets and their impact on mortality, and head, face and neck injuries following motorcycle crashes.

Objectives

To assess the effects of wearing a motorcycle helmet in reducing mortality and head and neck injury following motorcycle crashes.

Search strategy

We searched the Cochrane Injuries Group Specialised Register, Cochrane Central Register of Controlled Trials (*The Cochrane Library* issue 2, 2007), MEDLINE (up to April 2007), EMBASE (up to April week 16, 2007), CINAHL (January 1982 to February 2003), TRANSPORT (up to issue 12, 2006) (TRANSPORT combines the following databases: Transportation Research Information Services (TRIS) International Transport Research Documentation (ITRD) formerly International Road Research Documentation (IRRD), ATRI (Australian Transport Index) (1976 to Feb 2003), Science Citation Index were searched for relevant articles. Websites of traffic and road safety research bodies including government agencies were also searched. Reference lists from topic reviews, identified studies and bibliographies were examined for relevant articles.

Selection criteria

We considered studies that investigated a population of motorcycle riders who had crashed, examining helmet use as an intervention and with outcomes that included one or more of the following: death, head, neck or facial injury. We included any studies that compared an intervention and control group. Therefore the following study designs were included: randomised controlled trials, non-randomised controlled trials, cohort, case-control and cross-sectional studies. Ecological and case series studies were excluded.

Data collection and analysis

Two authors independently screened reference lists for eligible articles. Two authors independently assessed articles for inclusion criteria. Data were extracted by two independent authors using a standard extraction form.

Main results

Sixty-one observational studies were selected of varying quality. Despite methodological differences there was a remarkable consistency in results, particularly for death and head injury outcomes. Motorcycle helmets were found to reduce the risk of death and head injury in motorcyclists who crashed. From four higher quality studies helmets were estimated to reduce the risk of death by 42% (OR 0.58, 95% CI 0.50 to 0.68) and from six higher quality studies helmets were estimated to reduce the risk of head injury by 69% (OR 0.31, 95% CI 0.25 to 0.38). Insufficient evidence was found to estimate the effect of motorcycle helmets compared with no helmet on facial or neck injuries. However, studies of poorer quality suggest that helmets have no effect on the risk of neck injuries and are protective for facial injury. There was insufficient evidence to demonstrate whether differences in helmet type confer more or less advantage in injury reduction.

Authors' conclusions

Motorcycle helmets reduce the risk of death and head injury in motorcycle riders who crash. Further well-conducted research is required to determine the effects of helmets and different helmet types on mortality, head, neck and facial injuries. However, the findings suggest that global efforts to reduce road traffic injuries may be facilitated by increasing helmet use by motorcyclists.

PLAIN LANGUAGE SUMMARY

Helmets are shown to reduce motorcyclist head injury and death

Motorcyclists are at high risk in traffic crashes, particularly for head injury. A review of studies concluded that helmets reduce the risk of head injury by around 69% and death by around 42%. There is, so far, insufficient evidence to compare the effectiveness of different types of helmet. Some studies have suggested that helmets may protect against facial injury and that they have no effect on neck injury, but more research is required for a conclusive answer. The review supports the view that helmet use should be actively encouraged worldwide for rider safety.

BACKGROUND

Road traffic injuries contribute significantly to mortality and the burden of disease throughout the world, but particularly in developing countries (Ameratunga 2006; Mohan 2002; Nantulya 2002). In many developing countries, the majority of those injured in road traffic crashes are pedestrians, cyclists and motorised two-wheel riders (that is, motorcycles, motor scooters etc) For instance, in 1994 in Malaysia, 57% of all road deaths were riders of motorised two-wheelers (Mohan 2002). The number of road fatalities attributed to motorised two-wheelers in industrialised countries, where four-wheeled private vehicles are more prevalent, is also disproportionately high (Mohan 2002). In 1998, in Britain, motorcycle riders accounted for less than 1% of total road users but contributed to 15% of those killed or seriously injured on the roads (DFT 1998). With increasing modernisation in many developing countries, road traffic deaths are increasing (Odero 1997), and traffic deaths are projected to become the third most important health problem by 2020 (Murray 1996). Interventions to address this rising epidemic should, therefore, be assessed.

Injuries to the head, following motorcycle crashes, are a common cause of severe morbidity and mortality (Bachulis 1988; Sosin 1990). Intuitively, wearing of motorcycle helmets should reduce the number of such head injuries. Results from large scale ecological type studies have suggested that when helmet use rates increase with implementation of a law, injury and mortality rates decrease (Branas 2001; McSwain 1990; Sosin 1990). However, in both developing and developed countries, resistance to legislation on motorcycle helmets still coexists with debate on the effectiveness of motorcycle helmets in reducing morbidity and mortality.

Arguments against helmets for motorcycle riders include the possibility that they increase the risk of neck injuries in crashes (Krantz 1985) and could decrease rider visibility. Questions also surround the effectiveness of helmets in reducing mortality, given the severity of other body injuries sustained by riders in motorcycle crashes.

The type of helmet worn, correct fastening of helmets and cost are secondary issues that are particularly relevant to motorcycle helmet usage in developing countries.

A review of the effectiveness of bicycle helmets, compared with 'no helmet', found they had significant advantage in reducing head and facial injuries (Thompson 2002). Motorcycles, like bicycles, are a convenient and popular form of transport. However, motorcycles travel at far higher speeds than bicycles, with the potential for greater impact in accidents and hence greater injury. This review collates the current available evidence on helmets and their impact on mortality, and head, face and neck injuries following motorcycle crashes. A reliable estimate of the effectiveness of helmets will assist in road safety research, particularly in assessing the likely cost-effectiveness of introducing helmet legislation and enforcement in countries where motorcycle injuries are common and legislation does not currently exist.

O B J E C T I V E S

To quantify the effectiveness of wearing a motorcycle helmet in reducing mortality and head, face and neck injury following motorcycle crashes.

M E T H O D S

Criteria for considering studies for this review

Types of studies

Studies comparing an intervention and control group were considered. This included any randomised controlled trials, controlled trials, cohort and retrospective cohort studies and case-control studies. Ecological-type studies and case (or case series) studies were excluded. For ethical reasons, randomised controlled trials on interventions such as motorcycle helmets are rarely, if ever, conducted. Evidence for motorcycle helmets in injury prevention, therefore, often comes from non-randomised trials. Control of confounders in non-randomised study design is particularly important to achieve a valid estimate of effect.

Types of participants

Motorcycle riders of all ages who have been involved in any type of crash.

Types of interventions

• Helmets, both full and partial coverage worn on the head.
• Type of helmet (full with face-shield and chin-bar, full without face shield, partial without face shield etc), whether the helmet is fastened and whether the helmet meets relevant safety standards was recorded if possible.

Types of outcome measures

• Motorcycle rider death.
• Motorcycle rider head injury including brain, skull and facial injury or concussion.
• Motorcycle rider neck injury or cervical spine injury.

Search methods for identification of studies

Electronic searches

The following databases were searched:

- Cochrane Injuries Group's specialised register (searched 25 April 2007),
- Cochrane Central Register of Controlled Trials (*The Cochrane Library* issue 2, 2007),
- MEDLINE (January 1966 to April 2007),
- EMBASE (January 1985 to April 2007),
- CINAHL (January 1982 to February 2003),
- TRANSPORT (issue 12, 2006) (includes Transportation Research Information Services (TRIS) International Transport Research Documentation (ITRD) formerly International Road Research Documentation (IRRD),
- ATRI (Australian Transport Index),
- Science Citation Index.

The full search strategies can be found in Appendix 1.

Searching other resources

Reference lists of identified studies and topic reviews were searched for relevant articles, as well as road safety organisation web sites and conference proceedings. Road safety organisations were contacted for published and unpublished material, including relevant pilot projects and demonstration projects.

Data collection and analysis

Selection of studies

Two authors examined the titles and abstracts obtained through the search strategy and identified potentially eligible studies. A more inclusive strategy was employed at this stage. The full text of all potentially eligible articles was obtained. Study authors were contacted for clarification if necessary. Full text articles were independently examined by two authors for eligibility, based on inclusion criteria. Duplicate studies were excluded. Any disagreements were resolved by discussion.

Data extraction and management

Two authors independently extracted data from each study on the study type, interventions and outcome measures. Additional information on intervention subgroups (helmet type), confounding factors, number of participants, loss to follow-up and blinding of outcome assessors were collected if appropriate. For studies where raw data was provided but the study authors had not calculated an estimate of effect, two authors independently extracted the raw data and calculated the estimate of effect using RevMan software.

Assessment of risk of bias in included studies

Quality was assessed by taking into consideration whether non-participants were described and whether there had been adjustment for potential confounders (such as gender, age, alcohol use, other injuries, motorcycle speed and environmental factors). The authors took steps in case-control studies to minimise recall bias. Quality was assessed independently during data extraction and then compared between two reviewers. Differences were resolved by discussion with a third author.

Data synthesis

The effect of the interventions on the outcome measures was analysed. Studies were classified according to study type. For outcomes with a similar measure of effect, a combined estimate of effect was calculated. The outcome measure used for analysis was the odds ratio (OR). Graphical presentation was done by means of a Forest plot, to show the OR and 95% confidence interval for each study. The RevMan statistical package was used for data analysis. The generic inverse variance method for adjusted OR was employed for those studies providing confounder adjusted effect measures. Unadjusted data was also analysed in RevMan to give unadjusted ORs. Subgroup analysis by study type was conducted for the outcome of head injury.

R E S U L T S

Description of studies

See: Characteristics of included studies; Characteristics of excluded studies.

For additional details of individual studies see 'Characteristics of included studies' table.

A total of 61 eligible studies were identified. No randomised controlled trials or other controlled trials were found. There was great variation in study designs and quality. However, the majority of identified studies were cross-sectional designs that examined one or more of the outcomes (head injury, mortality, facial injury or neck injury) in relation to helmet use. There were four studies utilising a 'matched-pair' design and all of these examined the outcome of mortality in relation to helmet use. Four case-control studies and one cohort study were also identified.

Thirty studies examined the outcome of death in relation to helmet use, 36 examined head injury, 16 examined neck injury and 10 examined facial injury. Eight studies looked at the combined outcome of head and/or neck injury in relation to helmet use and seven studies examined different types of helmets in relation to a variety of outcomes of head injury, neck injury and facial injury.

The observational data were obtained from a wide variety of settings, including some developing countries (Conrad 1996; Nakahara 2005; Phuenpathom 2001; Sood 1988). However, the majority of studies were based on populations from developed countries. The study participants were identified by a variety of means including motorcycle crash presentations at hospital, linking data from police reported crashes to hospital data, databases of routinely collected information (such as the Fatal Accident Reporting System (FARS) in the US) and trauma databases. Some investigators only examined the outcome of interest in a dead population (Krantz 1985; O'Connor 2002; Romano 1991; Sarkar 1995). The only cohort study (Lin 2001) recruited college students as participants.

Notably some studies used the same study population or overlapping periods of data for their study population. Both Weiss 1992 and Goldstein 1986 used different statistical models on data collected by Hurt 1981 to estimate helmet effectiveness and the four matched pair studies used overlapping time periods from the FARS database. For this reason, these studies could not be included in a meta-analysis.

Risk of bias in included studies

For additional details of individual studies see 'Characteristics of included studies' table.

While there was great variation in the quality of the 61 included studies, in general the methodological quality was poor. Only 14 studies made any attempt to measure and control for confounders in their estimate of effect and a further five studies presented their results stratified by potential confounders. In addition to this, most studies were either affected by selection bias or had the potential for this to influence their results. While some investigators made attempts to include all motorcycle crash victims in their defined geographic area (Gabella 1995; Rowland 1996), many studies simply examined patients at a single 'level one' trauma centre or a few non-randomly selected hospitals. Others were only able to capture a convenience sample or a small percentage of crash victims in their area (for instance only 20%, Hurt 1981) or had to exclude large proportions of crash victims due to missing data, non-linkage of data or loss to follow up. The potential for selection bias to occur in these situations is a real possibility but difficult to quantify. Few studies (Carr 1981; Kraus 1995c; Norvell 2002; Orsay 1995) were able to provide any data to demonstrate that participants excluded from their study due to selection issues were not significantly different from those included.

As most studies relied on retrospectively obtained data, measurement of outcome and exposure generally had consistent methodology. Outcomes were measured by medical records or death certificates. Similarly, exposure measurement relied mostly on medical or police records although some investigators relied on direct on-the-scene measurement (Hurt 1981; O'Connor 2002) or crash victim self-report (Lin 2001; O'Connor 2005). Due to the fact that no studies were controlled trials, and most relied on retrospective data, blinding of outcome and exposure assessors did not occur.

Quality ranking scales can be unreliable and may introduce bias into the review process (Clarke 2003; Greenland 1994). As there were no randomised controlled trials identified, the only objective criteria to subgroup studies was found to be study design and whether potential confounders had been controlled for. Those studies that attempted to control for confounders were ranked as higher quality. This resulted in a subgroup of 19 higher quality studies; 10 examined the outcome of death in relation to helmet use and 11 examined the outcome of head injury. Of those examining the outcome of death, four were matched pair studies using overlapping periods of the FARS database (Anderson 1996; Deutermann 2004; Evans 1988; Norvell 2002), five were cross-sectional design (Goldstein 1986; Hundley 2004; Keng 2005; Rowland 1996; Sauter 2005) and two were cross-sectional designs that gave an estimate of death in relation to helmet use compared with no helmet use stratified by different variables including speed, alcohol use and time of crash (Nakahara 2005; Shibata 1994). Of those that investigated the outcome of head injury in relation to helmet use, two used a case-control design (Gabella 1995; Tsai 1995), seven a cross-sectional study design (Christian 2003; Goldstein 1986; Javouhey 2006; Romano 1991; Rowland 1996; Sauter 2005; Weiss 1992) and two were cross-sectional studies that stratified their estimate of effect by speed (Chang 1981; Kraus 1975). Of the two studies that examined neck injury, one was a case-control study (O'Connor 2005) and the other cross-sectional (Sauter 2005). Two studies examined composite outcomes of neck and spine injury (Sauter 2005) and head and neck (Keng 2005). The study by Sauter 2005 also examined the outcome of facial injuries.

Effects of interventions

In some studies the inverse of the reported odds ratios/relative risks (ORs/RRs) are reported in this review to conform with the *Cochrane Database of Systematic Reviews* (CDSR) convention for expressing outcomes.

Mortality

Studies controlling for confounders

Due to heterogeneity in study design and overlap of study participants, some of the studies controlling for confounders could not be included in a meta-analysis. From the four studies that could (Hundley 2004; Keng 2005; Rowland 1996; Sauter 2005), a pooled odds ratio (OR) of 0.58 (95% confidence interval (CI) 0.50 to 0.68) was calculated, indicating that helmets are protective against death. There was no heterogeneity between study results (P = 0.95). The four matched pair studies on overlapping populations had similar estimates for helmet-wearing being protective against death (adjusted risk ratio (RR) 0.61, 95% CI 0.54 to 0.70 in Norvell 2002; adjusted RR 0.65, 95% CI 0.58 to 0.72 Anderson 1996; effectiveness 28% (± 8%) Evans 1988; effectiveness 39% (no confidence interval) Deutermann 2004). Nakahara 2005 also showed that helmets were significantly protective against death in analyses separately stratified by age, alcohol use and time of day of crash. Shibata suggested that speed may be an effect modifier on the odds of death for helmeted riders and therefore estimated for those travelling 30 to 50km/h (adjusted OR 0.03, 95% CI 0.002 to 0.42) and those traveling over 50km/hr (adjusted OR 0.47, 95% CI 0.086 to 2.32). Goldstein 1986's maximum likelihood probit model found that helmet-wearing resulted in no change in the probability of survival after accounting for kinetic energy of the rider and alcohol use.

Studies not controlling for confounders

Of the 19 studies, four found helmets compared with no helmet significantly protective against death (OR 0.56, 95% CI 0.32 to 0.99 Copes 1991, OR 0.32, 95% CI 0.14 to 0.68 Heilman 1982, OR 0.64, 95% CI 0.51 to 0.81 Petridou 1998, OR 0.42, 95% CI 0.33 to 0.53 Eastridge 2006), three studies found helmets protective against death but provided no estimate of statistical significance (Wilson 1989: effectiveness 29%, Carr 1981: OR 0.16, Johnson 1996: OR 0.64), and 13 found a non-significant effect of helmet-wearing on death (range: OR 0.14, 95% CI 0.02 to 1.01 Ding 1994 to OR 1.21, 95% CI 0.60 to 2.44 Offner 1992). Petridou 1998's stated measure of effect only compared the odds of death with the odds of injury and was described as being 'adjusted'. However, the authors have been unable to contact the investigator to clarify what this implied. Wilson 1989 used a 'matched pair' study design but made no attempt to adjust for potential confounders such as rider age and gender. Sixteen of these studies could be combined to give an overall unadjusted estimate of helmet effectiveness for reducing mortality (OR 0.58, 95% CI 0.46 to 0.73).

Head injury

Studies controlling for confounders

Eleven studies found motorcycle helmets compared with no helmets significantly protect against head injury in motorcyclists who crash. Only six studies gave estimates that could be combined in a meta-analysis: adjusted OR 0.41, 95% CI 0.21 to 0.81 Gabella 1995; adjusted OR 0.26, 95% CI 0.14 to 0.47 Tsai 1995; adjusted OR 0.26, 95% CI 0.18 to 0.40 Romano 1991; adjusted OR 0.32, 95% CI 0.21 to 0.50 Rowland 1996; adjusted OR 0.23, 95% CI 0.14 to 0.53 Christian 2003; adjusted OR 0.43, 95% CI 0.30 to 0.67 Sauter 2005. The estimate quoted by Tsai 1995 was for 'full-face' helmets only compared with no helmet. The combined adjusted estimate of effect for any head injury for all six studies is OR 0.31, 95% CI 0.25 to 0.38. There was no significant heterogeneity (P = 0.39). When subgrouping studies by study type was undertaken, the combined adjusted estimate from the two case-control studies gave similar estimates to the combined adjusted estimate from the cross-sectional studies: OR 0.32, 95% CI 0.20 to 0.51 versus OR 0.30, 95% CI 0.24 to 0.39.

Using the same data but different mathematical models to control for confounders, Goldstein 1986 and Weiss 1992 both found helmets significantly reduce the probability of head injuries in motorcycle crashes. Javouhey 2006 compared helmeted and non-helmeted motorcyclists to restrained car occupants for head injury and found the odds ratio to be significantly different in the two: adjusted OR 2.75, 95% CI 2.15 to 3.52 and adjusted OR 18.07, 95% CI 12.78 to 25.54 in helmeted and non-helmeted motorcyclists respectively. Keng 2005 estimated helmets to be protective for the combined outcome of head and neck injury (adjusted OR 0.38, 95% CI 0.37 to 0.40).

For the two cross-sectional studies that stratified head injury estimates by speed, Kraus 1975 compared the outcome of serious head injury versus non-serious head injury and found a non-significant effect of helmets, i.e. for those travelling less than 50km/hour (OR 0.59, 95% CI 0.09 to 3.70) and those travelling 50 to 113km/hr (OR 0.31, 95% CI 0.07 to 1.44). Chang 1981 compared an outcome of head injury with no head injury and found helmets to be similarly protective at different speeds, that is, those travelling less than or equal to 35mph (OR 0.38, 95% CI 0.22 to 0.65) and those travelling greater than or equal to 36mph (OR 0.35, 95% CI 0.24 to 0.50).

Studies not controlling for confounders

The 25 remaining studies that did not adjust for confounders in their estimate of effect were remarkably consistent and, overall, found helmets to be significantly protective compared with no helmets for head injuries. The overall combined estimate from 18 studies (see meta-analysis) was OR 0.40, 95% CI 0.37 to 0.42, range 0.26, 95% CI 0.19 to 0.36 Hurt 1981, to 0.83, 95% CI 0.25 to 2.69 Krantz 1985, and there was no evidence of heterogeneity (P = 0.42). The only cohort study (Lin 2001) found head injuries occurred significantly more often in unhelmeted crash victims than helmeted (4.7% compared with 1.9%, P = 0.004). Johnson 1996 and LaTorre 2002 also provided estimates of helmet effectiveness but did not give raw data that could be combined in the meta-analysis. Johnson 1996 found helmets to be 65% effective (no CI given) and LaTorre 2002 found an OR of 0.23, 95% CI 0.03 to 0.48. Similarly, Johnson 1995, Lloyd 1987, May 1989 and Van Camp 1998 gave data that could not be used in the meta-analysis but these studies demonstrated that alternate measures of head injury such as average nervous system score and incidence of skull fracture were lower in helmeted riders compared with non-helmeted riders who crashed.

Neck injury

Studies controlling for confounders

Two studies attempted to control for confounders but differences in the way results were reported meant the studies could not be combined. O'Connor 2005 case-control study which selected motorcyclists with injuries to other parts of the spine as controls and showed results stratified by age and motorcycle size found no difference in the risk of neck or spine injury between helmeted and non-helmeted riders. Estimates from O'Connor 2005 varied from OR 0.35, 95% CI 0.04 to 3.37, to OR 4.07, 95% CI 0.56 to 29.73 in different strata with the unstratified estimate OR 1.14, 95% CI 0.30 to 4.36. Goldstein 1986's model attempted to control for confounders and predicted that beyond a critical impact speed (13mph) the average weighted helmet increases the probability of neck injury. The cross-sectional study by Sauter 2005 examined a combined outcome of neck and spine injury with an adjusted OR 1.11, 95% CI 0.77 to 1.67.

Studies not controlling for confounders

Of the 14 studies with no adjustment for confounders, only one found that motorcycle helmet compared with no helmet significantly protects against neck injury (Sarkar 1995 OR 0.11, 95% CI 0.01 to 0.91). All other studies found a non-significant relationship between helmets and neck injury. From the 12 studies providing data that could be combined, there was no significant effect of helmets on neck injuries (OR 0.85, 95% CI 0.66 to 1.09, test for heterogeneity P = 0.69).

Facial injury

Only one study provided confounder adjusted estimates (Sauter 2005) and found helmets to significantly protect against facial injury (OR 0.34, 95% CI 0.24 to 0.48). Of the studies without adjustment for confounders, five found helmets compared with no helmet significantly protective against facial injury following a crash (Eastridge 2006; Johnson 1995; Lin 2001; Rowland 1996; Gopalakrishna 1998) and the other four found a non-significant effect of helmet wearing on facial injury. The combined estimate from eight eligible studies found helmets compared with no helmets significantly protect against facial injury (OR 0.41, 95% CI 0.32 to 0.52). There was significant heterogeneity (P = 0.005). Lin found 5.3% of unhelmeted crash victims compared with 2.6% of helmeted crash victims sustained facial injuries (P = 0.007).

Helmet type

Of the seven studies that examined different helmet types, only one adjusted for confounders. Tsai found full-face helmets compared with no helmet significantly protective against head injury (adjusted OR 0.26, 95% CI 0.14 to 0.47). However, helmets without a chin-bar and less head coverage (defined as full helmet or partial coverage helmet) compared with no helmet were not significantly protective against head injury (adjusted OR 0.72, 95% CI 0.38 to 1.37). Hurt 1981 found that full-face helmets and non-full-face helmets compared with no helmet were both significantly protective against head injury (OR 0.29, 95% CI 0.17 to 0.49 and OR 0.24, 95% CI 0.16 to 0.36, respectively). Both Cannell 1982 and Vaughan 1977 found full-face helmets compared with open-faced helmets (or 'jet helmet') provided no significant advantage in relation to head injury (OR 1.13, 95% CI 0.34 to 3.76 and OR 0.88, 95% CI 0.58 to 1.32, respectively).

Vaughan 1977, Krantz 1985, O'Connor 2002 and O'Connor 2005 found that full-face helmets compared with open-faced helmets (or 'jet helmet') had no significant effect on neck injuries (OR 0.85, 95% CI 0.26 to 2.80, OR 0.84, 95% CI 0.07 to 9.56, OR 0.76, 95% CI 0.15 to 3.81 and OR 1.08, 95% CI 0.27 to 3.12, respectively). Similarly Cannell 1982 found that full-face helmets compared with open-face helmets did not have a significant effect on facial injuries.

DISCUSSION

As no randomised controlled trials were found, we relied on observational data for this review. Although we identified many studies that addressed the study question, on the whole the methodological quality was poor. A variety of different study designs were included, as long as the design allowed for a control or comparison group. Cross-sectional studies were the predominant study type identified. Although cross-sectional studies are frequently criticised as the outcome is prone to 'length-biased sampling' (Rothman 1998), for this review, investigators have measured only new events (incident injuries or death after a motorcycle crash) over the study period rather than the prevalence of these conditions. Hence, in this case, this criticism does not apply and the cross-sectional studies included are in fact similar to a case-control design.

Besides study design, the only objective quality ranking criteria applicable to studies included in this review was measurement and adjustment for confounding. Factors such as motorcycle speed, alcohol consumption, rider age and gender are often associated with motorcycle crash fatalities and injuries (Braddock 1992; Kelly 1991; Lin 2001; Offner 1992; Wick 1998) and there is good reason to suspect these factors may differ between those who wear motorcycle helmets and those who do not (Hurt 1981; Johnson 1995; Shankar 1992; Skalkidou 1999). Hence in non-randomised studies, control of these potential confounders is essential for a valid estimate of effect and therefore this criterion was used as the main quality item to differentiate higher and lower quality studies.

Despite using observational studies and the difficulties with poor quality, there is no doubt that motorcycle helmets compared with no helmets reduce the likelihood of head injuries. The estimate of effectiveness ranges from OR 0.23 to 0.35. Notably, among the confounder adjusted estimates, the case-control studies provided a similar estimate to that from the cross-sectional studies confirming the argument that a difference in the study design of included papers in this review is unlikely to bias results. Studies that made no attempt to adjust for confounding gave a more conservative estimate of effect and the study by Chang 1981 that stratified helmet effectiveness by speed further supports this finding (that is, the overall unadjusted estimate of helmet effectiveness (OR 0.43, 95% CI 0.33 to 0.57) is more conservative than the estimates obtained after stratification). Given the variability among the types of confounders adjusted for in individual studies, it is difficult to postulate reasons for this observed difference between adjusted and unadjusted estimates. However, the overall consistency among the results irrespective of study design, setting and quality issues confirms the effectiveness of helmets in protecting against head injury.

Studies estimating the effect of helmets on mortality were very consistent in their results, suggesting a protective effect. Among the studies controlling for confounders, the four cross-sectional studies provided an overall adjusted estimate of OR 0.58, 95% CI 0.50 to 0.68, although the potential confounders adjusted for (including age, alcohol use, speed limit, vehicle damage and physical environment) varied substantially. This estimate is similar to that from the four matched pair studies. Shibata 1994 found that for motorcyclists who crashed at lower speeds helmets significantly decreased the risk of death but at speeds greater than 50km/hr there was no significant benefit from wearing a helmet although the direction of the OR in both strata was the same, that is suggesting a protective effect. The studies by Keng 2005 and Sauter 2005 made attempts to factor in motorcycle speed in their estimates by adjusting for the speed limit at the crash site. However this may not reflect the true motorcycle speed at the time of the crash. The matched pair studies control for speed by the nature of their study design however there may be differences in motorcycle riders who ride as pairs such as different dynamics at the time of crash that afford more protection than in single riders. Hence it is difficult to make any conclusions about the impact of speed on the protective effect of helmets on mortality. Overall the combined estimate from the 'unadjusted' studies OR 0.58 (95% CI 0.46 to 0.73) was similar to the adjusted studies. Hence the evidence shows helmets reduce mortality compared with no helmets but this should be further investigated in relation to their interaction with speed.

There is insufficient evidence to make conclusions about helmet effects on neck and facial injuries, although findings are not inconsistent with a protective effect on facial injuries. Of the two studies that attempted to adjust for confounders for the outcome of neck injury, one (O'Connor 2005) found no effect although the numbers of eligible participants were small and the third (Goldstein 1986) has been criticised for flawed statistical methodology (Bedi 1987; Weiss 1992). Similarly, there is insufficient evidence to make firm conclusions on the effectiveness of different helmet types. Only one study adjusted for confounders when providing an estimate of effect comparing full-face helmets and non-full-face helmets with no helmet, and the author (Tsai 1995) suggested the study result may be biased by measurement error due to the fact that the quality of 'full' and 'partial coverage' helmets in Taiwan are suboptimal as many do not have an impact absorbing liner.

The findings from this review, particularly in relation to helmet effectiveness for head injury, are consistent with the conclusions drawn from other literature. Before-after studies conclude that following the implementation of a helmet law, a reduction in motorcycle-related head injuries occurs (Chiu 2000; Kraus 1995a) while the repeal of a law results in increased death and injury (McSwain 1984). Ecological-type studies also suggest that motorcycle helmet laws result in a reduction in motorcycle head injury-related deaths (Sosin 1990) and that helmet laws result in a reduction in motorcycle related death rates (Branas 2001).

Given the significant impact head injuries have on the burden of disease worldwide (McKenzie 2000) the results of this review should be contemplated widely. However, care must be taken in generalising the findings. Of note, most higher quality studies were conducted in developed countries where more technologically advanced emergency services exist and some studies used only dead populations (O'Connor 2002; Romano 1991) or paired motorcycle riders (Anderson 1996; Evans 1988; Norvell 2002). Head injury definitions mostly did not include minor injuries such as soft-tissue or scalp injuries so the results of this review relate primarily to more serious head injuries such as brain injury and skull fractures. Also, Shibata 1994 noted that in the relevant study period, Japan had no emergency on-the-scene medical treatment which may affect the estimates of mortality given in this study.

Few studies discussed the issue of helmet quality and measured whether helmets worn by riders met safety standards. Tsai 1995 commented on the quality of helmets in Taiwan but only a few authors actually examined helmets worn by study participants to ensure they complied with safety standards. It has been noted in both high and middle/low income countries that 'counterfeit helmets' are available (Peek-Asa 1999; Thompson 2003) and one study has suggested that such helmets may result in more injury in crashes (Peek-Asa 1999). Most of the studies in this review came from developed countries, where this is unlikely to be a major issue, but the results from this review should be viewed with this potential misclassification in mind. Furthermore, the enforcement of helmet safety standards must go hand in hand with motorcycle helmet legislation which has been shown to be effective in increasing helmet wearing rates (Kraus 1995c).

Various authors suggest that protective measures such as helmets and seat belts may decrease an individual's perception of risk and thereby increase their propensity to engage in risk-taking behaviour (Adams 1999; Wilde 2002). Although this review did not aim to investigate the effect of wearing motorcycle helmets on the likelihood of increasing risk-taking behaviour such as speeding, this issue of 'risk compensation' deserves mention. No doubt the arguments supporting and refuting this theory need to be considered when applying the findings of this review to policy.

In terms of reporting risk reduction, the odds ratio, the primary measure of effect in most of the included studies, provides an estimate of the relative risk provided by helmets in the population, that is, motorcycle riders who crash (Hennekens 1987; Kahn 1989; Rothman 1998; Schlesselman 1982). Therefore it is appropriate to estimate that motorcycle helmets reduce the risk of head injury by 69% and death by 42%.

AUTHORS' CONCLUSIONS

Implications for practice

Observational studies that control for confounders demonstrate that helmets are effective in reducing head injuries in motorcyclists who crash by 69% and death by 42%. There is some evidence to suggest that the effect on mortality may be modified by other crash factors such as speed at impact. Currently no conclusive evidence exists on the effect of motorcycle helmets on neck or facial injuries.

Implications for research

Further high quality studies are required to address the issue of whether motorcycle helmets influence neck injury, facial injury and the effects of motorcycle speed on the risk of death for motorcycle riders wearing helmets. In addition, the effectiveness of different helmet types needs to be addressed in a well conducted controlled trial. Issues of cost-effectiveness and enforcement of industry approved helmets are further issues that need to be considered.

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* *Indicates the major publication for the study*

CHARACTERISTICS OF STUDIES

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

Anderson 1996

Methods	Matched pair cohort study.
Participants	Motorcycle crash driver/passenger pairs, identified by FARS (entire USA) from 1976-1989, where both riders 14 years or older where one or both died. (N=8,816 pairs).
Interventions	Motorcycle helmet use compared with no helmet use.
Outcomes	Death within 30 days of crash.
Notes	25% of eligible pairs excluded due to missing data on potential confounders or helmet use. Confounders measured incl: age, gender, seating position, 'police reported BAL' from FARS. Study design assumed participant pairs matched for environmental factors including speed, road conditions etc. FARS validity dependent upon police reporting - differential misclassification of exposure and confounders unlikely. Provided a fatality risk ratio adjusted for age, gender and seating position (N=8816 pairs) and another adjusted for 'police reported BAL' (N=4265 pairs). Authors note that when results stratified by year, effectiveness increases. Helmet effectiveness decreased in crashes involving collisions with other vehicles compared with non-collision crashes and helmets appeared more effective in less severe crashes.

Anonymous 1994

Methods	Retrospective cross-sectional study.
Participants	Police reported motorcycle crash victims where participants were able to be linked with medical record via probabilistic linkage in state of Wisconsin for 1991. (N=3009)
Interventions	Motorcycle helmet use compared with no helmet use.
Outcomes	Death and head injury as recorded in medical record.
Notes	No potential confounders measured. Approx 6% missing helmet status excluded. Also states approx 7% linking matches made by computer incorrect.

Bachulis 1988

Methods	Retrospective cross-sectional study.
Participants	Motorcycle crash victims presenting to one hospital in the USA from Jan 1, 1983 to May 31 1987. (N=367)
Interventions	Motorcycle helmet use compared with no helmet use.
Outcomes	Death, brain injury, neck injuries and maxillofacial injuries as defined from medical record.

Bachulis 1988 *(Continued)*

Notes	No potential confounders measured.

Brandt 2002

Methods	Retrospective cross-sectional study.
Participants	Motorcycle crash victims over 15 years of age presenting to a level 1 trauma centre from July 1996 to Oct 2000. (N=216)
Interventions	Motorcycle helmet use compared with no helmet use.
Outcomes	Mortality and head and/or neck injury AIS as recorded on trauma registry.
Notes	Potential confounders measured but none adjusted for. Raw numbers only given for mortality. Head, neck and facial injuries results recorded as average AIS compared between helmeted and unhelmeted riders.

Cannell 1982

Methods	Prospective cross-sectional study.
Participants	Selection of motorcycle crashes identified from police and ambulance radio links and by hospital casualty officers over 4 month period from 1978-1979. (N=45)
Interventions	Full-face helmets compared with open-face helmets.
Outcomes	Head injury and maxillofacial injury as recorded on medical records.
Notes	Besides age, no potential confounders measured and none adjusted for. 11 deaths excluded. No indication of comparability of those selected for inclusion compared with general motorcycle riders in area.

Carr 1981

Methods	Case-control study.
Participants	Participants were motorcycle crash injured patients recruited from 7 hospitals in the area selected because they were more likely include patients with major trauma. Cases were those who had head injury (N=96) and controls were non-head injured participants (N=177).
Interventions	Motorcycle helmet use compared with no helmet use.
Outcomes	Head trauma (and severity) as defined by medical records.

Carr 1981 *(Continued)*

Notes	Potential confounders measured but not adjusted for. 31% participants had unknown helmet status. Quotes OR for death with helmet use as intervention factor but no CI given (OR 0.16).

Chang 1981

Methods	Retrospective cross-sectional study.
Participants	Systematic sampling of motorcycle accident cases from Wisconsin state accident records from 1977 to 1979. (N=888)
Interventions	Motorcycle helmet use compared with no helmet use.
Outcomes	Head injury as classified on scene - not verified by medical records.
Notes	Potential confounders such as speed and 'manner of collision' measured and results stratified by these factors. Found for all strata of speeds greater than 25mph, there was a significant difference in head injury incidence between helmeted and non-helmeted. 3% missing helmet data.

Christian 2003

Methods	Retrospective cross-sectional study.
Participants	Motorcycle drivers involved in a crash identified from one level 1 trauma centre trauma registry from 1995 to 2000. (N=311)
Interventions	Motorcycle helmet use compared with no helmet use.
Outcomes	Head injury and serious head injury defined from ICD9 and AIS codes of medical record.
Notes	Measured potential confounders such as age, gender, riding season, type and time of accident, drug screen, blood alcohol from trauma registry and adjusted for this in estimate of effect. Only small loss of participants due to unknown helmet use.

Conrad 1996

Methods	Prospective cross-sectional study.
Participants	Motorcycle riders injured and admitted to any of the 4 hospital EDs in the region. (N=475)
Interventions	Motorcycle helmet use compared with no helmet use.
Outcomes	Head injury and serious head injury based on medical records.

Conrad 1996 (*Continued*)

Notes	Potential confounders measured but not adjusted for. 9% excluded due to unknown helmet use.

Copes 1991

Methods	Retrospective cross-sectional study.
Participants	Injured motorcycle riders who were treated at participating Level 1 & 2 trauma centres across the USA from 1982-1988 and identified on the trauma registry. (N=1066)
Interventions	Motorcycle helmet use compared with no helmet use.
Outcomes	Mortality, head injury and/or spinal cord injury as recorded on medical records (trauma registry).
Notes	Potential confounders measured but not adjusted for. 87% of selected participants had missing helmet data and were excluded from analysis. Found average severity of head/brain/spinal injury significantly less for helmeted versus unhelmeted riders.

Deutermann 2004

Methods	Matched-pair analysis.
Participants	Motorcycle driver/passenger pairs who crashed on the same motorcycle and one rider died. Participants identified from the Fatality Analysis Reporting System (FARS) during 1993-2002.
Interventions	Motorcycle helmet use compared with no helmet use.
Outcomes	Death.
Notes	Study design means that participants are matched for speed and other environmental conditions.

Diemath 1989

Methods	Retrospective cross-sectional study.
Participants	Patients (ages 16 to 24 years) that sustained a head injury following a motorcycle or moped accident. Selection of participants not described. (N=192)
Interventions	Motorcycle helmet use compared with no helmet use.
Outcomes	Mortality and head injury severity.
Notes	Potential confounders measured but not adjusted for. No description of method of selection of participants and all from a subgroup of those already with a head injury.

Ding 1994

Methods	Retrospective cross-sectional study.
Participants	Motorcycle crash presenting to hospital ED in 1990. (N=2498)
Interventions	Motorcycle helmet use compared with no helmet use.
Outcomes	Death (or survival) up to 4 months after discharge from hospital. Head injury (as per AIS score).
Notes	Measured confounders but none adjusted for. <20% missing data due to either unknown helmet use or injury status.

Eastridge 2006

Methods	Cross-sectional study.
Participants	Motorcyclists who crashed identified from National Highway Transportation Study Administration (NHTSA) General Estimates System (GES) database for pre-hospital data and National Trauma Data Bank (NTDB) for hospital data from 1994 to 2002.
Interventions	Motorcycle helmet use compared with no helmet use.
Outcomes	Pre-hospital death, brain, facial and neck injury (based in AIS).
Notes	No confounders measured.

Evans 1988

Methods	Matched pair cohort study.
Participants	Motorcycle crash driver/passenger pairs identified by FARS (entire USA) during 1975-1986 where both riders were 16 years or older and one or both riders died. Pairs had to be matched for age (driver and passenger ages within 3 years of one another) and only males included (N=4714 fatalities).
Interventions	Motorcycle helmet use compared with no helmet use.
Outcomes	Death within 30 days of crash.
Notes	Study design matched for age, gender (by excluding females as too few all female pairs). This resulted in loss of 42% fatality data. Authors found driver seating position had greater risk of fatality.

Fledkamp 1977

Methods	Prospective cross-sectional study.
Participants	Consecutive motorcycle drivers presenting as trauma victims to one hospital from 1972-1974. (N=124)
Interventions	Motorcycle helmet use compared with no helmet use.
Outcomes	Death because of head trauma. Head trauma - defined as a "contusion". Facial injuries.
Notes	Potential confounders not measured nor controlled for. No loss to follow up or missing information data provided. Only outcome of 'death because of head trauma' used because inadequate definitions given for other outcomes.

Gabella 1995

Methods	Case-control study.
Participants	Cases and controls identified from traffic accident reports of motorcycle crashes investigated by Division of Motor Vehicles during Jan 1, 1989 to Dec 31, 1990 in El Paso County (Colorado, USA) i.e.: all motorcycle crashes where there was personal injury or property damage. Cases were those who crashed and sustained a traumatic brain injury or skull fracture identified thought the Colorado dept of health severe head injury surveillance system (based on death certificates, discharge ICD-9 codes, text diagnoses). (N=71) Controls were those who crashed and did not sustain a head injury (i.e.: were not identified by the head injury surveillance system). (N=417)
Interventions	Motorcycle helmet use compared with no helmet use.
Outcomes	Head injury: traumatic brain injury or skull fracture as defined by ICD-9 codes or comparable medical record diagnoses.
Notes	Confounders such as DUI, age, passenger status, crash time and type, motorcycle speed, citation for various motorcycle offences measured and adjusted for. Misclassification of minor head injury cases (i.e.: superficial lacerations or concussions) as controls is possible and if helmets are protective, this will result in underestimate of effect.

Goldstein 1986

Methods	Prospective cross-sectional study.
Participants	Used participants from Hurt 1981 study. See description of this study. (N=644)
Interventions	Motorcycle helmet use compared with no helmet use.
Outcomes	Fatality, head and neck injury.

Goldstein 1986 (*Continued)*

Notes	Uses econometric model to take account of confounders such as age, alcohol consumption, rider on-road experience and speed in predicting effect of motorcycle helmets on outcomes. Model used has been criticised. Excluded some data (28%) due to missing values and for some models assigned a mean value to missing data.

Goodnow 1990

Methods	Retrospective cross-sectional study.
Participants	Identified initially from Motor Vehicle Accident files for motorcycle crashes occurring in 4 counties during Sept 1, 1986 to Dec 31, 1987 where at least one crash victim was transported to hospital. (N=742)
Interventions	Motorcycle helmet use compared with no helmet use.
Outcomes	Head injury as defined by a medical record.
Notes	Potential confounders measured but not adjusted for. 21% loss of participants due to missing injury data or unknown helmet data.

Gopalakrishna 1998

Methods	Retrospective cross-sectional study.
Participants	Non-fatally injured motorcyclists admitted to any of 28 non-randomly selected hospitals across 10 Californian counties from 1991 to 1993. (N=4895)
Interventions	Motorcycle helmet use compared with no helmet use.
Outcomes	Facial injuries defined from medical records.
Notes	Potential confounders measured but not adjusted for. 15% of participants excluded due to unknown helmet status.

Heilman 1982

Methods	Retrospective cross-sectional study.
Participants	Included by linking databases including death certificates, hospital data, highway patrol motor vehicle crash report over 1977 to 1980 for one US state. (N=2874)
Interventions	Motorcycle helmet use compared with no helmet use.
Outcomes	Head/neck/facial injury and deaths defined from medical records and death certificates.
Notes	Potential confounders measured but not adjusted for. Unknown proportion of participants lost in linkage process, 11% unknown helmet status.

Hundley 2004

Methods	Cross-sectional study.
Participants	Motorcyclists injured in traffic accidents identified by the National Trauma Data Bank (NTDB) during 1994-2002. Information in data bank from 130 hospitals across 25 US States.
Interventions	Motorcycle helmet use compared with no helmet use.
Outcomes	Death.
Notes	Confounders (alcohol and drug use) measured and results presented stratified. Information on helmet use missing for 22%.

Hurt 1981

Methods	Prospective cross-sectional study.
Participants	Non-random selection of reported motorcycle crash victims that investigators were notified of by emergency services and able to investigate on-scene. (N=878)
Interventions	Motorcycle helmet use compared with no helmet use. Different helmet types.
Outcomes	Head and neck injuries in relation to helmet or no helmet use and type of helmet use.
Notes	Potential confounders measured but not adjusted for.

Javouhey 2006

Methods	Cross-sectional study.
Participants	All victims injured in a road crash identified from a road trauma registry in the Rhone region of France.
Interventions	Motorcycle helmet use compared with no helmet use.
Outcomes	Traumatic brain injury.
Notes	Unknown helmet use for 34% of motorcyclists in study population. Confounder adjusted estimate provided.

Johnson 1995

Methods	Retrospective cross-sectional study.
Participants	All injured motorcycle crash victims admitted to a regional level 1 trauma centre over 4 years. (N=331)
Interventions	Motorcycle helmet use compared with no helmet use.

Johnson 1995 (*Continued)*

Outcomes	Injuries including skull fracture, facial fracture and cervical spine injury as recorded in medical records.
Notes	Potential confounders measured but not adjusted for. No mention of any lost data or participants. Incidence of skull fracture found to be significantly less in those wearing helmets (P<0.01).

Johnson 1996

Methods	Retrospective cross-sectional study.
Participants	All drivers of motorcycles involved in police reported crashes in 7 US states that were able to be linked to injury databases (EMS, hospital). (N=10353)
Interventions	Motorcycle helmet use compared with no helmet use.
Outcomes	Head injury and death as confirmed through linkage with medical records and death certificates.
Notes	Potential confounders measured but not adjusted for. Unclear as to lost data through non-linkage. Also 38% unknown helmet use in NY state data and one state, Utah, excluded due to inability to distinguish between helmeted and non-helmeted riders. No raw data or confidence intervals provided with estimates of effect. Also provided information on seat belt effectiveness.

Kelly 1991

Methods	Prospective cross-sectional study.
Participants	Motorcycle riders involved in a crash presenting less than 24 hours after the crash to one of 8 hospitals in 4 counties. Engine size must be 150cc or greater and have known helmet status. (N=398)
Interventions	Motorcycle helmet use compared with no helmet use.
Outcomes	Death and injuries including head and/or neck injury, facial injury and neck injury as recorded from medical records.
Notes	Potential confounders measured but not adjusted for with injury as outcome (confounders controlled for in outcome of overall injury severity).

Keng 2005

Methods	Cross-sectional study.
Participants	All participants in an accident where there was either and injury and/or death identified from the Traffic Accident Files (TAF) collected by the National Police Agency (NPA) of Taiwan during 1999-2001.
Interventions	Motorcycle helmet use compared with no helmet use.

Keng 2005 *(Continued)*

Outcomes	Probability of death, probability of head or neck injury.
Notes	All crashes including motorcycle accidents involving only one vehicle or more than 2 vehicles, accidents involving large vehicles, pedestrians or bicycles were excluded. Estimates adjusted for age, sex, type of vehicle involved in crash, speed limit, physical environment.

Krantz 1985

Methods	Retrospective cross-sectional study.
Participants	All motorcycle and moped riders killed in traffic accident identified through autopsy reports from 1977-1983. (N=132)
Interventions	Motorcycle helmet use compared with no helmet use. Full-face and open-face helmet types.
Outcomes	Head injuries and neck injuries as defined on autopsy report.
Notes	Potential confounders not measured. Authors stated that autopsies are conducted on all deaths in traffic accidents in Sweden and therefore likely to have included all deaths in region.

Kraus 1975

Methods	Retrospective cross-sectional study.
Participants	All motorcycle riders who crashed and required medical treatment as identified from police reports, death certificates, hospital records in county. Non-county residents and females excluded. (N=626)
Interventions	Motorcycle helmet use compared with no helmet use.
Outcomes	Serious and non-serious head injury. No clear indication of definition of head injury although serious head injury defined as that resulting in death, hospitalisation, bone fracture and requiring continuous medical care beyond 2 visits.
Notes	Potential selection bias as only 628 male drivers responded to questionnaire of 1273 injured persons. Furthermore, only 268 of the 628 male drivers had speed and helmet use data for the stratified analysis.

Kraus 1995

Methods	Retrospective cross-sectional study.
Participants	Drivers from fatal or severe injury motorcycle crashes reported to police in LA county from July 1988 to Oct 1989 where drivers records could be linked to coroner or hospital records. (N=477)

Kraus 1995 *(Continued)*

Interventions	Motorcycle helmet use compared with no helmet use.
Outcomes	Head Injury from medical records. Fatality from medical record or coroner.
Notes	Potential confounders measured but no adjusted for. 60% data missing due principally to non-linkage of reported crashes.

Kraus 1995a

Methods	Retrospective cross-sectional study.
Participants	Non-fatally injured motorcycle crash victims presenting to 18 non-randomly selected hospitals in 10 California counties over a period Jan 1, 1991 to Dec 31, 1993.
Interventions	Motorcycle helmet use compared with no helmet use.
Outcomes	Head injury and severe head injury as recorded on medical records.
Notes	No potential confounders measured. <20% participants excluded due to missing helmet or injury data.

LaTorre 2002

Methods	Prospective cross-sectional study.
Participants	injured motorcycle riders following a crash aged 14-35 years presenting to 2 selected hospitals in Italy during Jan to June 1999. (N=736).
Interventions	Motorcycle helmet use compared with no helmet use.
Outcomes	Head Injury based on data collected by investigators or those recruited by investigators.
Notes	Potential confounders measured by none adjusted for. No apparent missing data.

Lin 2001

Methods	Cohort study.
Participants	Junior college students from 3 randomly selected colleges in a rural and urban area of Taiwan. Participants followed for 18 months from Nov 1994 to June 1996. (N=1889 crashes)
Interventions	Motorcycle helmet use compared with no helmet use.

Lin 2001 (*Continued*)

Outcomes	Head, neck and facial injury reported by participants on a questionnaire and supplemented by school records.
Notes	Potential confounders measured and although states a multivariate analysis conducted, this is not shown and attempts to contact authors have been unsuccessful. Average response rate to questionnaire 92%. 20% participants lost to follow up due to graduation of one year. Participants could be included more than once in this study as investigators collected relevant injury data for each crash sustained by the participant and there were more crashes (N=1889) than individual riders involved (N=1284) and therefore despite having raw numbers, no RR were extrapolated. Reliability of questionnaire responses assessed through re-test of 150 randomly selected questionnaires.

Lloyd 1987

Methods	Retrospective cross-sectional study.
Participants	Injured motorcycle riders presenting to one hospital in Texas during Feb 1985 to Jan 1986. (N=88)
Interventions	Motorcycle helmet use compared with no helmet use.
Outcomes	Head injury as recorded on trauma registry.
Notes	No potential confounders measured. Only reported a difference in average nervous system score between helmeted and non-helmeted riders. No estimate of statistical significance provided. 45% participants excluded due to unknown helmet use status.

Luna 1981

Methods	Retrospective cross-sectional study.
Participants	Motorcycle accident victims presenting to a US trauma centre from July 1, 1978 to Nov 30, 1979. (N=263)
Interventions	Motorcycle helmet use compared with no helmet use.
Outcomes	Death within first week following admission to hospital. Major head injury from medical records.
Notes	Potential confounder not measured. 15% participants with unknown helmet use.

May 1989

Methods	Retrospective cross-sectional study.
Participants	Victims of motorcycle crashes requiring transport according to county triage criteria to one trauma centre. (N=213)

May 1989 (*Continued)*

Interventions	Motorcycle helmet use compared with no helmet use.
Outcomes	Head injury as recorded on medical record.
Notes	Potential confounders measured but not adjusted for. 5% participants unknown helmet use. Found significant head injuries accounted for 9% of injuries in helmeted patients compared with 37% in unhelmeted.

Murdock 1991

Methods	Retrospective cross-sectional study.
Participants	Motorcycle crash victims seen a one level 1 trauma centre over 45 months. (N=347)
Interventions	Motorcycle helmet use compared with no helmet use.
Outcomes	Head and/or neck injury and neck injury alone as described in medical records. Death as recorded from medical record.
Notes	No potential confounders measured. 28% of participants had unknown helmet status.

Nakahara 2005

Methods	Cross-sectional study.
Participants	Motorcyclists injured in one municipality in Thailand and admitted to the regional Trauma Centre during 1998-2002.
Interventions	Motorcycle helmet use compared with no helmet use.
Outcomes	Death.
Notes	Confounders measured and some stratified results presented. 2% with unknown helmet use.

Norvell 2002

Methods	Matched pair cohort study.
Participants	Motorcycle crash driver/passenger pairs, identified by FARS (entire USA) during 1980-1998, where riders were 16 years or older and one or both riders in the pair died. (N=9,222 pairs)
Interventions	Motorcycle helmet use compared with no helmet use.
Outcomes	Death within 30 days of crash.

Norvell 2002 (*Continued*)

Notes	Study design matches for motorcycle characteristics such as type, speed and environmental factors. 20% pairs excluded due to missing data. Those with missing helmet data had similar age and gender distribution as those with helmet data. Confounders measured and adjusted for included gender, age, rider position.

O'Connor 2002

Methods	Prospective cross-sectional study.
Participants	Motorcyclists who died in a crash in the Adelaide (Australia) metropolitan area between 1983-1991. (N=159)
Interventions	Full face motorcycle helmet compared with open-faced motorcycle helmet.
Outcomes	Cervical spine injury verified by autopsy examination (i.e. only in motorcyclists who died).
Notes	Authors comment on subgroups with head impact cases and helmet retention. Study measured confounders such as age, head impact crash type, BAL but did not find any significant predictor of cervical spine injury and therefore did not control for these in final OR. Study base includes all crashes in the area but selects from this a subset of all those who died. Presents evidence to suggest there is no systematic difference between those motorcycle riders who live or die and the type of helmet worn. 8% missing autopsy data.

O'Connor 2005

Methods	Hospital based case-control study.
Participants	Motorcycle crash victims admitted to the spinal cord injuries unit of one hospital during 1982-1988. Cases were riders with a cervical spinal cord injury and controls those with injuries to other segments of the spinal cord.
Interventions	Motorcycle helmet use compared with no helmet use. Full face helmets compared to open face helmets. Self-report or relative-reported.
Outcomes	Cervical spine injury.
Notes	Excluded 15% of participants as they either had died or were unable to be interviewed. Confounders not adjusted for although results presented stratified by age and motorcycle size.

Offner 1992

Methods	Retrospective cross-sectional study.
Participants	Motorcycle crash victims admitted to a level 1 trauma centre between Jan 1, 1985 to Jan 1 1990. (N=425)
Interventions	Motorcycle helmet use compared with no helmet use.
Outcomes	Death, head injury and neck injury as recorded in medical record.

Offner 1992 *(Continued)*

Notes	Potential confounders measured. Gives an estimate effectiveness of helmets for mortality and head injury weighted by a non-head Injury severity score. 14% participants have no helmet data.

Orsay 1994

Methods	Retrospective cross-sectional study.
Participants	Motorcycle crash victims identified from 28 hospital databases across 4 US states. (N=1056)
Interventions	Motorcycle helmet use compared with no helmet use.
Outcomes	Head Injury according to AIS from medical records. Mortality from medical records and some on-the-scene ambulance and police data. Cervical spine injury as recorded in medical records.
Notes	Potential confounders measured by none adjusted for. <20% participants excluded due to lack of helmet use data.

Orsay 1995

Methods	Retrospective cross-sectional study.
Participants	Motorcycle crash victims identified via a state public health trauma registry including all level 1 & 2 trauma centres in state from July 1, 1991 to Dec 31, 1992. (N=819)
Interventions	Motorcycle helmet use compared with no helmet use.
Outcomes	Head Injury according to AIS.
Notes	Potential confounders measured but none adjusted for. 26% of those identified had missing helmet status but investigators noted no significant difference in demographics of those with missing helmet status.

Petridou 1998

Methods	Retrospective cross-sectional study.
Participants	Identified by traffic police as any motorcycle riders involved in a motor vehicle accident where at least one person was killed or injured in 1985 and 1994 in Greece.
Interventions	Motorcycle helmet use compared with no helmet use.
Outcomes	Death rather than injury according to traffic police statistical department.

Petridou 1998 (*Continued)*

Notes	Measured age and gender and states final estimate of effect is adjusted for confounders but does not state what these are. Attempts to contact authors to clarify this have been unsuccessful. Authors state that approximately 20% of information was missing due to incomplete returns.

Phuenpathom 2001

Methods	Prospective cross-sectional study.
Participants	Injury motorcycle riders directly transferred to one of two selected hospital emergency departments where the accident occurred in the Hadyai municipality from April to Sept 1997. (N=581)
Interventions	Motorcycle helmet use compared with no helmet use.
Outcomes	Head and/or neck injury according to AIS.
Notes	Potential confounders measured but not adjusted for.

Romano 1991

Methods	Retrospective cross-sectional study.
Participants	All fatally injured motorcyclist, moped, motorscooter and minibike riders as identified by California FARS during 1987-1988 and able to be linked with California MCOD and SMD files with known helmet status. (N=1025)
Interventions	Motorcycle helmet use compared with no helmet use.
Outcomes	Head injury in those who died defined by ICD-9 codes 800-803, 850-854 inclusive.
Notes	Reports adjusted OR for odds of head injury with helmet use adjusted for gender, seating position, cycle damage and crash type. Authors report limitation of high proportion (40%) of deaths have unspecified injuries thereby potential misclassification of those with head injury. Authors recalculated OR re-classifying those with unspecified injuries as non-head injuries and found that OR still showed helmets protective against death. Confounders such as speed, BAL not considered.

Rowland 1996

Methods	Retrospective cross-sectional study.
Participants	Motorcycle drivers only who crashed in Washington state in 1989 as identified by State patrol records and linked to hospital and death records.
Interventions	Motorcycle helmet use compared with no helmet use.

Rowland 1996 (*Continued)*

Outcomes	Head Injury defined by ICD-9 codes and then mapped to AIS scores. Death defined by death certificate. Facial injury defined as AIS>0.
Notes	Reports adjusted RR for risk of death with helmet use (Rivara 2003) and adjusted OR for odds of head injury with helmet use. Confounders measured included age, gender, locality of crash, environmental conditions. 23% participants missing from head injury data because of non-linkage.

Rutledge 1993

Methods	Retrospective cross-sectional study.
Participants	All motorcycle riders involved in a crash hospitalised in any of 8 level 1 or 2 trauma centres in state during Oct 1, 1987 to Jan 1, 1991. (N=460)
Interventions	Motorcycle helmet use compared with no helmet use.
Outcomes	Head injury defined by AIS from medical record.
Notes	Potential confounders measured but none adjusted for. 48% of participants excluded due to unknown helmet use.

Sarkar 1995

Methods	Retrospective cross-sectional study.
Participants	Dead motorcycle crash victims identified from police and coroner reports in one county from July 1, 1988 to Oct 31, 1989. (N=164)
Interventions	Motorcycle helmet use compared with no helmet use.
Outcomes	Head and/or neck injury, facial fracture or neck injury as recorded in medical record or autopsy.
Notes	Measured other injuries as potential confounders and stratified findings according to those with equally severe non-head injuries.

Sauter 2005

Methods	Cross-sectional study.
Participants	All motorcycle crash victims in Wisconsin identified from the Crash Outcome Data Evaluation System (CODES) in 2002.
Interventions	Motorcycle helmet use compared with no helmet use.

Sauter 2005 (*Continued)*

Outcomes	Death and head, facial, neck/spine injury based on AIS.
Notes	Excluded 20% because of missing 'critical' variables including helmet use. Estimates adjusted for age, alcohol use, speed limit and vehicle damage for outcome of death, age, alcohol and injury severity for other outcomes.

Shankar 1992

Methods	Retrospective cross-sectional study.
Participants	All motorcycle drivers involved in a crash that was reported to police and transported to hospital in Maryland USA during July 1987 to June 1988. (N=721)
Interventions	Motorcycle helmet use compared with no helmet use.
Outcomes	Head injury defined by medical records.
Notes	Potential confounders measured but none adjusted for. 25% participants had missing data and were excluded.

Shibata 1994

Methods	Retrospective cross-sectional study.
Participants	Traffic accidents reported by police in Fukuoka Prefecture (Japan) in 1990 categorised into motorcycle crashed and motorcar accidents. (N=1077)
Interventions	Motorcycle helmet use compared with no helmet use. Seat belt use compared with no seat belt use.
Outcomes	Death within 24 hours of accident compared to no injury for both motorcyclists and motorcar occupants. Only outcome for motorcyclists examined in review.
Notes	OR stratified by gender and only given for male riders. Compared population who died with those with no injuries. OR adjusted for age and alcohol use. Speed found to be an effect-modifier, therefore at speeds between 30-50km/h helmets have protective effect against death but at speeds >50km/hr the protective effect is not significant. Authors also note that at the time of the study, Japan had no on-scene emergency management of injuries which may affect generalisability of results.

Sood 1988

Methods	Prospective cross-sectional study.
Participants	Injured motorcycle riders seen by author in one hospital during May to Dec 1985. (N=302)

Sood 1988 *(Continued)*

Interventions	Motorcycle helmet use compared with no helmet use.
Outcomes	Head Injury measured by author according to AIS.
Notes	Unclear description of methodology including selection of participants and blinding of assessor.

Tsai 1995

Methods	Case-control study.
Participants	Motorcycle riders receiving care for crash injuries in the ED of one of 16 hospitals in Taipei (Taiwan) from August 1 to Oct 15 1990. Cases were those recieving care for head injuries. (N=562) ED Controls were randomly selected individuals seeking care for injuries other than head injuries. (N=789) Street Controls: Were photographs of uninjured, non-crash motorcycle riders matched for time and place of daytime cases. (N=1094)
Interventions	Motorcycle helmet use compared with no helmet use. Full-face motorcycle helmets compared to no helmet. Non-full face helmets (full helmet or partial coverage helmet) compared to no helmet.
Outcomes	Head injury defined as brain injury, cerebral concussion, skull fracture, clinically proven unconsciousness, amnesia or neurologic sequelae on a re-visit to the ED. Soft-tissue/scalp injuries are not included. Head injury severity as measured by GCS scores.
Notes	Reported comparative estimates for ED and street controls. One ED excluded because suspected bias in selection of participants (5% excluded). Confounders including gender, age, rider position, motorcycle type, weather, place of accident measured. Quasi-random sampling of participants and unable to guarantee completeness of sample but odds of helmet use for street controls found to be similar in ED cases and controls.

Van Camp 1998

Methods	Prospective cross-sectional study.
Participants	A consecutive sample of motorcycle and moped accident victims admitted to university hospitals in one town from May 1, 1992 to April 30, 1994. (N=221)
Interventions	Motorcycle helmet use compared with no helmet use.
Outcomes	Head injury, head injury severity and cervical spine injury as recorded from a medical record.
Notes	Stratified results according to non-head injuries (defined as a surrogate for kinetic energy) and found the ratio of head and facial injuries per a patient was more than double in non-helmeted patients compared with helmeted.

Vaughan 1977

Methods	Retrospective cross-sectional study.
Participants	Motorcycle accident victims as identified by routine crash data in Sydney during a three month period. (N=1552)
Interventions	Full face motorcycle helmets compared with jet-style motorcycle helmets.
Outcomes	Head injury, facial injury and neck injury from police reports and supplemented by medical records.
Notes	Older study may mean different helmet standards and manufacturing practices mean comparisons not generalisable. No confounders measured. Methodology brief and not always clear.

Wagle 1993

Methods	Retrospective cross-sectional study.
Participants	Motorcycle accident victims transferred to a major trauma centre on helicopter ambulance (Lifestar) over a 5 year period. (N=80)
Interventions	Motorcycle helmet use compared with no helmet use.
Outcomes	Cervical spine injury and fatality from medical records.
Notes	Potential confounders measured but none adjusted for.

Weiss 1992

Methods	Prospective cross-sectional study.
Participants	Used participants from Hurt 1981 study. See description of this study.
Interventions	Motorcycle helmet use compared with no helmet use.
Outcomes	Head injury.
Notes	Statistical model controlled for alcohol and speed of rider in estimating predicted effect of helmets. Found that helmets lead to 42% increase in riders with no head injury.

Wilson 1989

Methods	Matched pair cohort study.
Participants	Motorcycle crash driver/passenger pairs, identified by FARS (entire USA) from 1982-1987, where both riders 14 years or older where one or both died. (N=5292 riders)
Interventions	Motorcycle helmet use compared with no helmet use.

Wilson 1989 (*Continued)*

Outcomes	Death within 30 days of crash.
Notes	Confounders including rider gender and age not measured nor adjusted for. Helmet effectiveness 29% (no CI given). Effectiveness stratified by passenger (30%) and driver (27%).

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

Ankarath 2002	Only outcome reported in relation to helmet use is Glasgow Coma Scale (GCS) which is not specifically a measure of head injury.
Asogwa 1982	Inadequate exposure measurement (helmet wearing). Author stated helmet use could only be defined as those "possessing" a helmet and not necessarily wearing one and no attempt was made to distinguish between those actually wearing a helmet.
Balcerak 1978	Descriptive study that does not report outcomes in relation to helmet use.
Braddock 1992	No individual participant exposure data presented.
Byrd 1978	Intervention measured is "helmet contact" and not helmet use.
Chen 2006	Case series.
Chinn 1999	Examines mechanisms of head injury in motorcycle accidents and not effectiveness of helmet.
Dowdell 1988	Does not examine outcomes of injury in relation to helmet use.
Hell 1993	Case series.
Hitosugi 1999	Does not separate bicycle riders from motorcycle riders for intervention of helmet use.
Hitosugi 2004	Case series.
Hoffman 1977	Case series.
Kasantikul 2005	Intervention is not helmet use.
Konrad 1996	Case series of autopsy cases.
Rocchi 2005	Case series - only includes adolescents with craniofacial trauma.
Tham 2004	Intervention is not helmet use. Compares helmeted motorcyclists to other MVA victims e.g.: car, cyclist, pedestrian.
Thom 1993	Case series. No control group.

(*Continued*)

Turner 2004	Study design is before/after. Injury definitions are unclear.

DATA AND ANALYSES

Comparison 1. Motorcycle helmet versus no helmet

Outcome or subgroup title	No. of studies	No. of participants	Statistical method	Effect size
1 Death (adjusted)	4		Adjusted Odds Ratio (Random, 95% CI)	0.58 [0.50, 0.68]
2 Death (not adjusted)	16	18588	Odds Ratio (M-H, Random, 95% CI)	0.58 [0.46, 0.73]
3 Head Injury (adjusted)	6		Adjusted Odds Ratio (Random, 95% CI)	0.31 [0.25, 0.38]
3.1 Case-control studies	2		Adjusted Odds Ratio (Random, 95% CI)	0.32 [0.20, 0.51]
3.2 Cross-sectional studies	4		Adjusted Odds Ratio (Random, 95% CI)	0.30 [0.24, 0.39]
4 Head Injury (not adjusted)	18	25892	Odds Ratio (M-H, Random, 95% CI)	0.40 [0.37, 0.42]
5 Neck Injury (not adjusted)	12	13367	Odds Ratio (M-H, Random, 95% CI)	0.85 [0.66, 1.09]
6 Facial Injury (not adjusted)	8	17603	Odds Ratio (M-H, Random, 95% CI)	0.41 [0.32, 0.52]

Analysis 1.1. Comparison 1 Motorcycle helmet versus no helmet, Outcome 1 Death (adjusted).

Review: Helmets for preventing injury in motorcycle riders

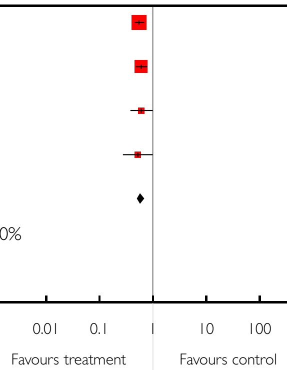
Comparison: 1 Motorcycle helmet versus no helmet

Outcome: 1 Death (adjusted)

Study or subgroup	log [Adjusted Odds Ratio] (SE)	Adjusted Odds Ratio IV,Random,95% CI	Weight	Adjusted Odds Ratio IV,Random,95% CI
Hundley 2004	-0.5798 (0.1138)		48.1 %	0.56 [0.45, 0.70]
Keng 2005	-0.4943 (0.1325)		35.5 %	0.61 [0.47, 0.79]
Rowland 1996	-0.4943 (0.2443)		10.4 %	0.61 [0.38, 0.98]
Sauter 2005	-0.6349 (0.3239)		5.9 %	0.53 [0.28, 1.00]
Total (95% CI)			**100.0 %**	**0.58 [0.50, 0.68]**

Heterogeneity: Tau^2 = 0.0; Chi^2 = 0.36, df = 3 (P = 0.95); I^2 =0.0%

Test for overall effect: Z = 6.89 (P < 0.00001)



Analysis 1.2. Comparison 1 Motorcycle helmet versus no helmet, Outcome 2 Death (not adjusted).

Review: Helmets for preventing injury in motorcycle riders

Comparison: 1 Motorcycle helmet versus no helmet

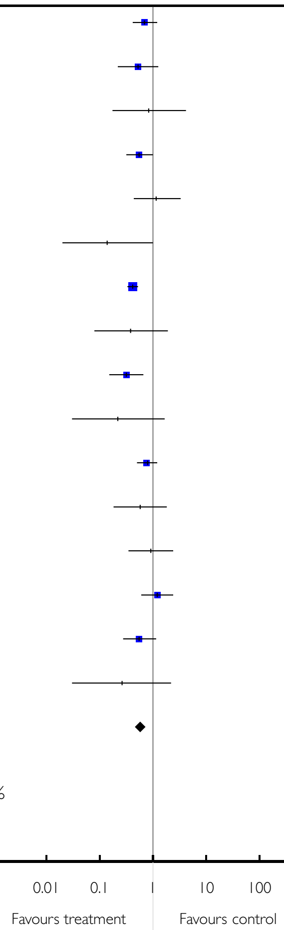
Outcome: 2 Death (not adjusted)

Study or subgroup	Helmet n/N	No helmet n/N	Odds Ratio M-H,Random,95% CI	Weight	Odds Ratio M-H,Random,95% CI
Anonymous 1994	19/994	55/2015		10.7 %	0.69 [0.41, 1.18]
Bachulis 1988	7/132	23/235		5.4 %	0.52 [0.22, 1.24]
Brandt 2002	7/174	2/42		1.9 %	0.84 [0.17, 4.19]
Copes 1991	37/810	20/256		9.9 %	0.56 [0.32, 0.99]
Diemath 1989	6/52	14/140		4.3 %	1.17 [0.43, 3.24]
Ding 1994	1/350	41/2016		1.3 %	0.14 [0.02, 1.01]
Eastridge 2006	135/3474	162/1854		19.5 %	0.42 [0.33, 0.53]
Fledkamp 1977	2/51	7/73		1.9 %	0.38 [0.08, 1.93]
Heilman 1982	9/1113	44/1761		7.2 %	0.32 [0.15, 0.65]
Kelly 1991	1/58	25/340		1.2 %	0.22 [0.03, 1.66]
Kraus 1995	41/134	124/343		13.2 %	0.78 [0.51, 1.20]
Luna 1981	4/101	11/162		3.3 %	0.57 [0.18, 1.83]
Murdock 1991	6/111	14/236		4.5 %	0.91 [0.34, 2.42]
Offner 1992	15/164	20/261		7.5 %	1.21 [0.60, 2.44]
Orsay 1994	9/252	50/804		7.1 %	0.56 [0.27, 1.15]
Wagle 1993	1/22	9/58		1.1 %	0.26 [0.03, 2.18]
Total (95% CI)	**7992**	**10596**		**100.0 %**	**0.58 [0.46, 0.73]**

Total events: 300 (Helmet), 621 (No helmet)

Heterogeneity: $Tau^2 = 0.06$; $Chi^2 = 21.95$, df = 15 (P = 0.11); I^2 =32%

Test for overall effect: Z = 4.59 (P < 0.00001)



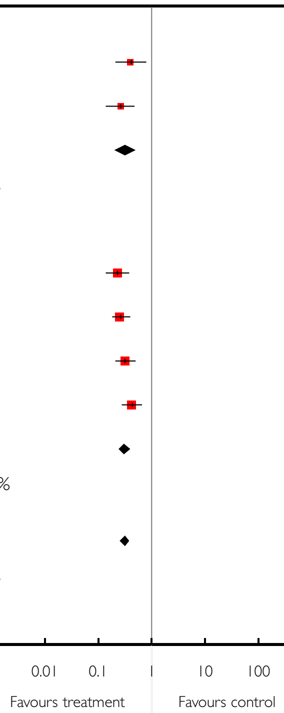
Analysis 1.3. Comparison 1 Motorcycle helmet versus no helmet, Outcome 3 Head Injury (adjusted).

Review: Helmets for preventing injury in motorcycle riders

Comparison: 1 Motorcycle helmet versus no helmet

Outcome: 3 Head Injury (adjusted)

Study or subgroup	log [Adjusted Odds Ratio] (SE)	Adjusted Odds Ratio IV,Random,95% CI	Weight	Adjusted Odds Ratio IV,Random,95% CI
1 Case-control studies				
Gabella 1995	-0.8796 (0.342)		8.9 %	0.41 [0.21, 0.81]
Tsai 1995	-1.3471 (0.3089)		10.9 %	0.26 [0.14, 0.48]
Subtotal (95% CI)			**19.8 %**	**0.32 [0.20, 0.51]**
Heterogeneity: Tau² = 0.00; Chi² = 1.03, df = 1 (P = 0.31); I² =3%				
Test for overall effect: Z = 4.89 (P < 0.00001)				
2 Cross-sectional studies				
Christian 2003	-1.4697 (0.2547)		15.9 %	0.23 [0.14, 0.38]
Romano 1991	-1.335 (0.2057)		23.9 %	0.26 [0.18, 0.39]
Rowland 1996	-1.1314 (0.2233)		20.4 %	0.32 [0.21, 0.50]
Sauter 2005	-0.8439 (0.2263)		19.9 %	0.43 [0.28, 0.67]
Subtotal (95% CI)			**80.2 %**	**0.30 [0.24, 0.39]**
Heterogeneity: Tau² = 0.02; Chi² = 4.11, df = 3 (P = 0.25); I² =27%				
Test for overall effect: Z = 8.98 (P < 0.00001)				
Total (95% CI)			**100.0 %**	**0.31 [0.25, 0.38]**
Heterogeneity: Tau² = 0.00; Chi² = 5.18, df = 5 (P = 0.39); I² =3%				
Test for overall effect: Z = 11.41 (P < 0.00001)				



Analysis 1.4. Comparison 1 Motorcycle helmet versus no helmet, Outcome 4 Head Injury (not adjusted).

Review: Helmets for preventing injury in motorcycle riders

Comparison: 1 Motorcycle helmet versus no helmet

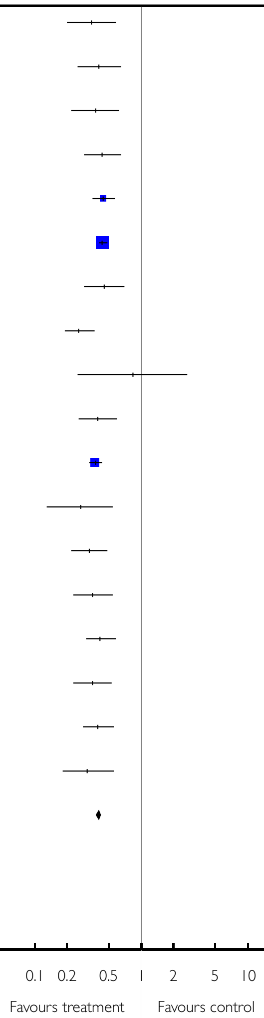
Outcome: 4 Head Injury (not adjusted)

Study or subgroup	Helmet n/N	No helmet n/N	Weight	Odds Ratio M-H,Random,95% CI
Anonymous 1994	17/994	97/2015	1.5 %	0.34 [0.20, 0.58]
Bachulis 1988	32/132	105/235	1.9 %	0.40 [0.25, 0.64]
Carr 1981	39/96	115/177	1.6 %	0.37 [0.22, 0.61]
Conrad 1996	102/318	82/157	2.7 %	0.43 [0.29, 0.64]
Ding 1994	140/363	1252/2135	7.8 %	0.44 [0.35, 0.56]
Eastridge 2006	1490/6119	1241/2914	38.3 %	0.43 [0.40, 0.48]
Goodnow 1990	31/247	120/495	2.3 %	0.45 [0.29, 0.69]
Hurt 1981	55/342	228/536	3.7 %	0.26 [0.19, 0.36]
Krantz 1985	86/102	26/30	0.3 %	0.83 [0.25, 2.69]
Kraus 1995	49/134	205/343	2.5 %	0.39 [0.26, 0.59]
Kraus 1995a	614/2408	745/1554	20.6 %	0.37 [0.32, 0.43]
Luna 1981	11/101	51/162	0.8 %	0.27 [0.13, 0.54]
Offner 1992	63/164	172/261	2.5 %	0.32 [0.22, 0.48]
Orsay 1994	28/252	210/804	2.3 %	0.35 [0.23, 0.54]
Orsay 1995	61/202	315/617	3.6 %	0.41 [0.30, 0.58]
Rutledge 1993	88/314	77/146	2.5 %	0.35 [0.23, 0.52]
Shankar 1992	68/330	156/391	3.7 %	0.39 [0.28, 0.55]
Sood 1988	52/233	33/69	1.3 %	0.31 [0.18, 0.55]
Total (95% CI)	**12851**	**13041**	**100.0 %**	**0.40 [0.37, 0.42]**

Total events: 3026 (Helmet), 5230 (No helmet)

Heterogeneity: $Tau^2 = 0.00$; $Chi^2 = 17.47$, df = 17 (P = 0.42); $I^2 = 3\%$

Test for overall effect: Z = 27.82 (P < 0.00001)



Analysis 1.5. Comparison 1 Motorcycle helmet versus no helmet, Outcome 5 Neck Injury (not adjusted).

Review: Helmets for preventing injury in motorcycle riders

Comparison: 1 Motorcycle helmet versus no helmet

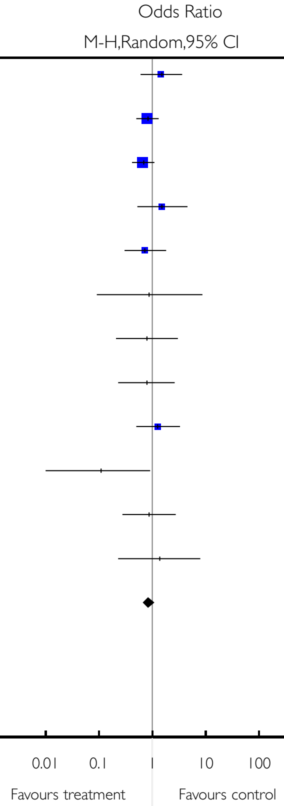
Outcome: 5 Neck Injury (not adjusted)

Study or subgroup	Helmet n/N	No helmet n/N	Weight	Odds Ratio M-H,Random,95% CI
Bachulis 1988	9/132	11/235	7.6 %	1.49 [0.60, 3.69]
Eastridge 2006	47/6119	27/2914	27.8 %	0.83 [0.51, 1.33]
Hurt 1981	27/342	60/536	27.7 %	0.68 [0.42, 1.09]
Johnson 1995	5/77	11/254	5.3 %	1.53 [0.52, 4.56]
Kelly 1991	6/58	46/340	7.7 %	0.74 [0.30, 1.81]
Krantz 1985	3/102	1/30	1.2 %	0.88 [0.09, 8.77]
Murdock 1991	3/111	8/236	3.5 %	0.79 [0.21, 3.04]
Offner 1992	4/164	8/261	4.2 %	0.79 [0.23, 2.67]
Orsay 1994	6/252	15/804	6.9 %	1.28 [0.49, 3.34]
Sarkar 1995	1/30	16/69	1.5 %	0.11 [0.01, 0.91]
Van Camp 1998	13/174	4/47	4.6 %	0.87 [0.27, 2.80]
Wagle 1993	2/22	4/58	2.0 %	1.35 [0.23, 7.95]
Total (95% CI)	**7583**	**5784**	**100.0 %**	**0.85 [0.66, 1.09]**

Total events: 126 (Helmet), 211 (No helmet)

Heterogeneity: $Tau^2 = 0.0$; $Chi^2 = 8.25$, df = 11 (P = 0.69); $I^2 = 0.0\%$

Test for overall effect: Z = 1.29 (P = 0.20)



Analysis 1.6. Comparison 1 Motorcycle helmet versus no helmet, Outcome 6 Facial Injury (not adjusted).

Review: Helmets for preventing injury in motorcycle riders

Comparison: 1 Motorcycle helmet versus no helmet

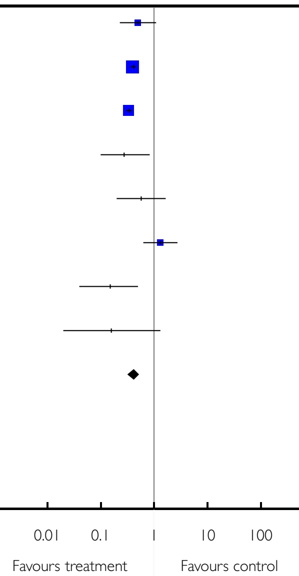
Outcome: 6 Facial Injury (not adjusted)

Study or subgroup	Helmet n/N	No helmet n/N	Odds Ratio M-H,Random,95% CI	Weight	Odds Ratio M-H,Random,95% CI
Bachulis 1988	9/132	30/235		8.0 %	0.50 [0.23, 1.09]
Eastridge 2006	952/6119	899/2914		35.0 %	0.41 [0.37, 0.46]
Gopalakrishna 1998	518/2874	799/2021		33.9 %	0.34 [0.30, 0.38]
Johnson 1995	4/77	41/254		4.8 %	0.28 [0.10, 0.82]
Kelly 1991	4/58	39/340		4.7 %	0.57 [0.20, 1.67]
Phuenpathom 2001	13/223	16/355		8.5 %	1.31 [0.62, 2.78]
Rowland 1996	3/945	20/957		3.8 %	0.15 [0.04, 0.50]
Sarkar 1995	1/30	12/69		1.4 %	0.16 [0.02, 1.32]
Total (95% CI)	**10458**	**7145**		**100.0 %**	**0.41 [0.32, 0.52]**

Total events: 1504 (Helmet), 1856 (No helmet)

Heterogeneity: $Tau^2 = 0.04$; $Chi^2 = 20.33$, df = 7 (P = 0.005); $I^2 = 66\%$

Test for overall effect: Z = 7.05 (P < 0.00001)



APPENDICES

Appendix 1. Search strategy

Cochrane Injuries Group's Specialised Register searched 25-04-07
(motor-cycl* or motorcycl* or motor-bik* or motorbik* or scooter* or moped* or moto or motocycl* or motocicl* or injur* or fatal* or accident* or crash* or prevent* or collide* or collision* or trauma*) and ((head and protect*) or (head and shield*) or (helmet*))

CENTRAL to issue 2, 2007
#1 Accidents/
#2 exp Accidents, Traffic/
#3 exp Accident Prevention/
#4 exp Motorcycles/
#5 motor-cycl* or motorcycl* or motor-bik* or motorbik* or scooter* or moped* or moto or motocycl* or motocicl*
#6 trauma* or injur* or fatal* or accident* or crash* or prevent* or collide* or collision*
#7 #1 or #2 or #3 or #4 or #5 or #6
#8 head near protect*
#9 head near shield*
#10 helmet*
#11 exp Head Protective Devices/
#12 #8 or #9 or #10 or #11

#13 #7 and #12

MEDLINE 1950-2007/April (week 2)

1. Accidents/
2. exp Accidents, Traffic/
3. exp Accident Prevention/
4. exp Motorcycles/
5. (motor-cycl$ or motorcycl$ or motor-bik$ or motorbik$ or scooter$ or moped$ or moto or motocycl$ or motocicl$).ab,ti.
6. (trauma$ or injur$ or fatal$ or accident$ or crash$ or prevent$ or collide$ or collision*).ab,ti.
7. or/1-6
8. (helmet$ or (head adj3 protect$)).ab,ti.
9. exp Head Protective Devices/
10. 7 or 8
11. 6 and 9
12. clinical trial.pt.
13. randomized.ti,ab.
14. randomised.ti,ab.
15. placebo.ti,ab.
16. drug therapy.fs.
17. randomly.ti,ab.
18. trial.ti,ab.
19. groups.ti,ab.
20. 11 or 12 or 14 or 15 or 16 or 17 or 18
21. exp animals/
22. exp humans/
23. 20 not (20 and 21)
24. 19 not 22
25. 10 and 23

EMBASE 1985-2007 (week 16)

1. exp clinical trial/
2. randomized.ti,ab.
3. randomised.ti,ab.
4. placebo.ti,ab.
5. randomly.ti,ab.
6. trial.ti,ab.
7. groups.ti,ab.
8. or/1-7
9. exp animals/
10. exp humans/
11. 9 not (9 and 10)
12. 8 not 11
13. exp Accident/
14. exp Traffic Accident/
15. exp MOTORCYCLE/
16. (motor-cycl$ or motorcycl$ or motor-bik$ or motorbik$ or scooter$ or moped$ or moto or motocycl$ or motocicl$).ab,ti.
17. (injur$ or fatal$ or accident$ or crash$ or prevent$ or collide$ or collision$ or trauma$).ab,ti.
18. or/13-17
19. exp helmet/
20. (helmet$ or (head adj3 protect$) or (head adj3 shield$)).ab,ti.
21. 19 or 20
22. 18 and 21
23. 12 and 22

TRANSPORT to issue 12, 2006 (includes; Transportation Research Information Services (TRIS); International Transport Research Documentation (ITRD) formerly International Road Research Documentation (IRRD) and TRANSDOC)
1. helmet*
2. head near protect*
3. head near shield*
4. #1 or #2 or #3
5. motor-cycl* or motorcycl* or motor-bik* or motorbik* or scooter* or moped* or moto or motocycl* or motocicl*
6. injur* or fatal* or accident* or crash* or prevent* or collide* or collision* or trauma*
7. #5 or #6
8. #4 and #7

WHAT'S NEW

Last assessed as up-to-date: 24 October 2007.

10 September 2008	Amended	Converted to new review format.

HISTORY

Protocol first published: Issue 3, 2003

Review first published: Issue 2, 2004

25 October 2007	New search has been performed	A search for new studies was conducted in April 2007. Eight additional studies were included in the review (Deutermann 2004; Eastridge 2006; Hundley 2004; Javouhey 2006; Keng 2005; Nakahara 2005; O'Connor 2005; Sauter 2005). The analyses and text of the review have been amended accordingly.

CONTRIBUTIONS OF AUTHORS

BL: Wrote drafts of the protocol and review, performed searches, reviewed titles and abstracts, reviewed full text of studies for inclusion, extracted data, performed analyses.

RI: Edited drafts of the protocol and review, reviewed titles and abstracts, reviewed full text of studies for inclusion, extracted data, provided epidemiological advice on methodology and interpretations.

RN: Edited drafts of the protocol and review, provided epidemiological advice on methodology and interpretations.

SBlows: Edited drafts of the protocol and review, reviewed full text of studies for inclusion, extracted data.

SBoufous: Edited drafts of the review, reviewed full text of studies for inclusion, extracted data.

SL: Edited drafts of the protocol and review, provided statistical advice.

DECLARATIONS OF INTEREST

None known.

SOURCES OF SUPPORT

Internal sources

- Institute for International Health, Australia.

External sources

- No sources of support supplied

INDEX TERMS

Medical Subject Headings (MeSH)

*Accidents, Traffic [mortality]; *Head Protective Devices; *Motorcycles; Craniocerebral Trauma [mortality; *prevention & control]; Facial Injuries [prevention & control]; Neck Injuries [prevention & control]; Skull Fractures [prevention & control]

MeSH check words

Humans