Peer-reviewed paper; submitted July 2016 accepted April 2017

# Do bicycle helmets reduce the risk of facial trauma? — a review

**Nichols GAL, Antoun JS, Al-Ani AH, Tong DC**


## Abstract

Facial injuries are often sustained during cycling accidents despite the mandatory use of safety helmets in New Zealand.

*Aims:* To evaluate the effectiveness of cycling helmets in preventing facial trauma. A secondary objective was to assess the impact of New Zealand legislation, concerning the mandatory use of safety helmets, on the prevalence of cycling-related facial trauma.

*Method:* Several keywords, such as "cycle accident" and "facial trauma", were used in PubMed to search for relevant articles that could be included in this non-systematic review.

*Results:* Some evidence supporting the role of bicycle helmets in preventing head injuries was found; however, comparatively fewer studies had investigated the effect of helmet use on the prevalence and nature of facial injuries. Based on the available data, safety helmets appear to reduce the risk of upper facial injuries but offer little or no protection to the mandible and some structures of the mid-face.

*Conclusions:* The impact of mandatory helmet use on the rate and pattern of facial injuries is still unclear. Most safety helmets do not provide physical protection to the mandible; however, further research is needed to evaluate whether design modifications would reduce the risk of fractures to this area.


## Introduction

New Zealand is well recognised globally for its cycling culture, particularly with regard to scenic recreational riding and international racing. Despite cycling being a popular leisure activity in New Zealand, there is only marginal use of bicycles for commuting purposes (Ministry of Transport, 2013; Tin Tin *et al.*, 2010). For example, Christchurch is one of the most bicycle-active cities in New Zealand, with more than 25% of the population using bicycles for recreational activities, but only 8% for commuting purposes (Lee and Chou, 2008). National figures appear even lower with the 2013 NZ census reporting only about 2% of the population using bicycles to commute to work (Ministry of Transport, 2013). One reason for this trend is the general sense of inadequate safety when commuting on roads (Ministry of Transport, 2013). Indeed, a large proportion of cyclists have reported that the development of dedicated bicycle lanes and reduced motor vehicle speeds are important factors that would encourage them to commute to work (Tin Tin *et al.*, 2010).

From a global perspective, cyclist fatalities in New Zealand are relatively low with approximately 2% of all road deaths caused by cycling-related accidents (Ministry of Transport, 2008). The rate of on-road cyclist fatalities in New Zealand is significantly lower than other developed countries such as the Netherlands (22%), Japan (16%) and Hungary (13%) (International Traffic Safety Data and Analysis Group, 2013). One reason for this low fatality rate has been ascribed to mandatory use of cycling helmets in New Zealand. Even though these laws are generally well-enforced (Clarke, 2012), the cost-effectiveness of compulsory helmet use remains controversial and the impact of helmet use on the risk of facial trauma is still unclear (Kopjar and Wickizer, 2000; Robinson, 2001; Taylor and Scuffham, 2002). In fact, some reports have suggested that mandatory helmet usage does not reduce the risk of bicycle-related injuries, but rather discourages cyclists from spending time on the road (Robinson, 2006). The severe nature of facial injuries raises important questions regarding the effectiveness of currently available protective gear and the need for public awareness campaigns.

The main objective of this review article was therefore to evaluate the effectiveness of cycling helmets in preventing facial trauma. A secondary objective was to assess the impact of New Zealand legislation on reducing the risk of cycling-related facial trauma.

## Facial fractures caused by cycling accidents

Fatalities and serious head injuries are often the primary focus of studies investigating the outcome of cycling accidents. By comparison, data on the nature and frequency of facial trauma is relatively scarce. In Christchurch, cycling accidents are the second most common cause of sports-related facial trauma, accounting for approximately 15% of all treated sports-related maxillofacial fractures (Antoun and Lee, 2008). The most common group of cyclists to sustain facial fractures are males between the ages of 10 and 19 years (Antoun and Lee, 2008). The increased risk of bicycle-related facial injuries among young males has also been noted elsewhere (Qing-Bin *et al.*, 2013).

Cyclists often sustain facial injuries because of falls off their bicycles (Lee and Chou, 2008; Thompson *et al.*, 1999). Of the facial sites affected, bicycle accidents often result in fractures of the mandible and mid-face (Figures 1 and 2), with the zygoma and mandibular condyle being the most commonly affected sites (Lee and Chou, 2008; Lindqvist *et al.*, 1986; Boffano *et al.*, 2013; Yamamoto *et*

**Figure 1.** A colour-coded illustration of the *skull* showing the relative risk of bicycle-related facial fractures by anatomical site; red zones indicate the greatest (relative) prevalence of trauma in skull, while yellow indicates the least (based on New Zealand data; Chou and Lee, 2008).

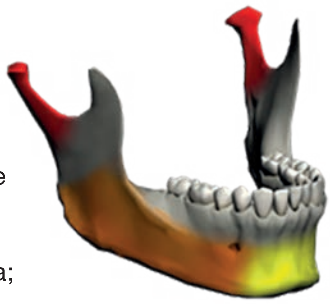

**Figure 2.** A colour-coded illustration of the *mandible* showing the relative risk of bicycle-related facial fractures by anatomical site; red zones indicate the greatest (relative) prevalence of trauma in mandible, while yellow indicates the least (based on New Zealand data; Chou and Lee, 2008).

*al*., 2011). Severe facial injuries, such as Le Fort II and III fractures, have also been reported following cycling accidents which involve high impact velocities and forces (Syed *et al*., 2013).

The upper facial bones, on the other hand, are generally less prone to injury with low fracture rates reported for the nasal and frontal bones. Interestingly, the pattern of facial fractures found in New Zealand is similar to that reported in other areas associated with low helmet use (Lindqvist *et al*., 1986; Yamamoto *et al*., 2011). This raises important questions regarding the effectiveness of currently available bicycle helmets in reducing facial trauma.

## Effectiveness of helmets in preventing facial injuries

There is some evidence to support the role of bicycle helmets in preventing head injuries (McDermott *et al*., 1993; Thomas *et al*., 1994; Maimaris *et al*., 1994).

A number of studies have suggested that bicycle helmets, regardless of type, provide substantial protection against head injuries for cyclists of all ages involved in crashes, including motor vehicle accidents (Thompson *et al*., 1999; Thompson *et al*., 1996A). In a Cochrane Collaboration systematic review, five case-control studies were analysed and it was concluded that helmets provide a 63-88% reduction in the risk of head and brain injuries across all age groups (Thompson *et al*., 1999). Facial injuries to cyclists occur at a rate nearly identical to that of head injuries, namely, 43 and 45 per 100 000 respectively (Thompson *et al.,* 1999); however, there is a lack of evidence regarding the effectiveness of bicycle helmets in preventing facial trauma (Table 1). The protective effect of bicycle helmets against facial injuries, therefore, remains a contentious issue in the literature (Hansen and Scuffham, 1995).

One reason for this controversy is that the majority of safety helmet designs do not cover the entire face, thus offering site-specific protection against facial injuries. Indeed, helmet use has been reported to reduce the risk of serious injury to the upper (OR = 0.36; 95% CI: 0.26-0.49) and mid-face regions (OR = 0.35; 95% CI: 0.24-0.50), but not the lower face (OR = 0.88; 95% CI: 0.72-1.07) (Thompson *et al*., 1996B). In support of these findings, it was found that helmet use reduced the risk of mid-to-upper facial injuries by 65%, but offered no significant protection against lower facial injuries (Thompson *et al.,* 1999). These findings are perhaps not surprising given that most helmets available on the market do not protect the mandible – a site that is highly susceptible to fractures in these accidents (Lee and Chou, 2008; Lindqvist *et al*., 1986; Boffano *et al*., 2013; Yamamoto *et al*., 2011).

The effect of different helmet types on the risk of facial injuries has also been explored (Hansen *et al.,* 2003). In comparison to non-helmet wearers, the use of hard shell helmets was reported to reduce the odds of sustaining head injuries (OR = 0.36; 95% CI: 0.21-0.60), but not facial injuries (OR = 0.90; 95% CI: 0.58-1.41) (Hansen *et al.,* 2003). Hard-shell helmets are still preferable to foam-type ones, which are associated with an increased risk of facial injury especially in young children under the age of nine years (OR = 1.87; 95% CI: 1.03-3.40) (Hansen *et al.,* 2003). The fit of safety helmets and the use of visible aids, such as lights, may also influence the risk of injury (Tin Tin

**Table I.** Summary of case-control studies that have investigated the effect of helmets on facial injuries.

| Study | Primary Outcome | Design | Sample Size | Population |
|---|---|---|---|---|
| Lindqvist *et al*., 1986 | Facial Fractures | Retrospective, observational study | 93 | Finland |
| Antoun and Lee, 2008 | Facial Fractures | Retrospective, observational study | 561 | New Zealand |
| Lee and Chou, 2008 | Facial Fractures | Retrospective, observational study | 63 | New Zealand |
| Yamamoto *et al*., 2011 | Facial Fractures | Retrospective, observational study | 307 | Japan |
| Boffano *et al*., 2013 | Facial Fractures | Retrospective, multi-centre, observational study | 208 | Italy, Holland |

*et al.*, 2013; Romanow *et al.*, 2014). In particular, poor-fitting helmets that tilt back (OR = 4.81, 95% CI: 2.74–8.46), shift (OR = 1.83, 95% CI: 1.04–3.19) or come off (OR = 3.31, 95% CI: 1.24–8.85) during bicycle accidents have been reported to increase the odds of facial injury (Romanow *et al.*, 2014).

It is noteworthy, however, that previous research has mostly been retrospective with very few well-designed prospective studies. Using a prospective study design, Harrison and Shepherd investigated the circumstances of maxillofacial injuries and the scope for preventative measures in Welsh cyclists over a 12-month period (Harrison and Shepherd, 1999). Information was collected prospectively on cyclists reporting to five emergency centres in regards to location and classification of the injury, presence of a head injury, circumstances of the accident, and the use of safety helmets (Harrison and Shepherd, 1999). The majority of these cyclists were young males, with only 14% of them wearing safety helmets at the time of the injury. The injuries recorded in these mostly non-helmet wearing cyclists were symmetrically distributed around the face. Nearly 70% of the sample had soft tissue abrasions and lacerations, with only 20% sustaining facial fractures (Harrison and Shepherd, 1999). The low rate of helmet use in the study, however, prevented the authors from making any definitive conclusions regarding the protective effect of safety helmets.

In New Zealand, there is limited data regarding the role of helmets in preventing facial injuries, with only one retrospective study investigating the distribution of facial fractures in a Christchurch sample (Lee and Chou, 2008). Utilising data from other studies is somewhat problematic since the characteristics of cyclists in other countries are likely to be different from those found in New Zealand. In the Christchurch study (Lee and Chou, 2008), for instance, injured cyclists reporting with maxillofacial injuries were significantly older than those reported in the South of Wales study (Harrison and Shepherd, 1999). Twenty-nine percent of the Christchurch sample involved individuals between the ages of 10-19 years, while almost two-thirds of the patients in the South Wales study were under the age of 15 years. Another important difference lies in the use of safety helmets, which was recorded in only 14% of cyclists in the South Wales study. Although helmet use was not recorded in the Christchurch study, this is likely to be relatively more because of New Zealand's transport laws concerning mandatory helmet use.

## The role of safety helmet legislation in reducing facial injuries

In 1994, New Zealand introduced legislation regarding mandatory bicycle helmet usage. Recent data from the Ministry of Transport seems to suggest a reduced risk for cyclists following the introduction of this legislation (International Traffic Safety Data and Analysis Group, 2013). For example, compliance in helmet usage improved from 18% to 92% between 1990 and 2011 (International Traffic Safety Data and Analysis Group, 2013). This increasing trend in helmet wear is consistent with those reported by other countries that have recently introduced bicycle helmet legislation. Although this data seems to support the role of helmets in preventing on-road fatalities, several studies have reported contradictory findings regarding the cost-effectiveness of safety helmet legislation, especially among adults (Kopjar and Wickizer, 2000; Robinson, 2001; Taylor and Scuffham, 2002; Hansen *et al.*, 2003).

To investigate the impact of legislation, Scuffham and Langley retrospectively examined serious injury trends in three age groups between 1980 and 1992 (Scuffham and Langley, 1997). Over this period, the voluntary wearing of helmets increased in the lead up to legislation by up to 84, 62 and 39% for primary school children, secondary school children and adults, respectively (Scuffham and Langley, 1997). Despite an increase in the number of cyclists wearing safety helmets, there was no concomitant decrease in the percentage of serious head injuries among cyclists. Contrasting results were found in another New Zealand study, which investigated the effect of safety helmet use on the prevalence of hospitalised head injuries between 1990 and 1996 (Povey *et al.,* 1999). For all age groups, the number of head injuries decreased with increasing helmet use for both non-motor vehicle accidents (between 24 and 32%) and motor vehicle crashes (20%) (Povey *et al.,* 1999). Interestingly, there was no change in the severity of head injuries for which cyclists were hospitalised over this period. In another retrospective study carried out in New Zealand, the proportion of serious head injuries reporting to the Emergency Department after collision with a moving motor vehicle was reported to have reduced from 65% to 33% following the introduction of compulsory helmet wear (Moyes, 2007). Scuffham *et al.* also investigated the impact of helmet use between 1988 and 1996, and found that mandatory helmet wear lead to a reduction in head injuries to cyclists of 19% (Scuffham *et al.,* 2000). Unfortunately, there are no studies to date that have investigated the effect of helmet legislation on the prevalence and distribution of facial injuries despite their relatively high frequency.

In addition to head injuries and on-road fatalities, some researchers have considered the effect of helmet legislation on other aspects of health and wellbeing. Findings from one study, which reported on the activity levels of cyclists over different time periods, suggest that safety helmet legislation has adversely affected general health by reducing the amount of time spent cycling (Clarke, 2012). This reluctance to cycle is believed to contribute directly to a significant lack of exercise, and indirectly to an increased rate of premature deaths (Clarke, 2012). It has also been suggested that mandatory use of safety helmets may mistakenly give cyclists the feeling of added security, which causes them to take more risks (Adams and Hillman, 2001). In the South of Wales study, for example, approximately 10% of those who lost control were helmet wearers, compared to 29% of those who collided with a stationary vehicle and 18% who were hit by a car (Harrison and Shepherd, 1999). The increased risk of colliding with oncoming vehicles has been attributed to the risk-taking behaviour of cyclists wearing helmets (Harrison and Shepherd, 1999). The fact that cyclists with previous crash histories are more likely to be involved in future accidents may also suggest that this group of high-risk cyclists are inherently more prone to injuries, regardless of helmet use. An alternative form of risk-taking behaviour among New Zealand adolescents includes not wearing safety helmets altogether (Coggan *et al.*, 1997).

In addition to helmet use, several other factors may also influence the risk of bicycle accidents including previous crash history, cycling in urban areas, and group cycling (Tin Tin *et al.*, 2013; Tin Tin *et al.*, 2014). Clearly, more research is needed to investigate the relationship between helmet use and risk-taking behaviour, especially among younger age groups. Moreover, the impact of mandatory helmet use on the rate of facial injuries in New Zealand requires further investigation.

## Considerations for overseas data

The present review has identified gaps in our knowledge of cycling-related facial injuries in New Zealand. The effect of helmet use on the prevalence of facial injuries is also still lacking, and primarily based on data originating from overseas studies. This data should be interpreted with caution, however. The South Wales study, with its particularly low rate of helmet use, demonstrates major challenges when applying international literature to New Zealand which is particularly unique in terms of the combination of road environment, cycling culture, and mandatory use of safety helmets.

With the exception of Australia, Finland and New Zealand (where legislative laws exist), the frequency of helmet use worldwide is reported to be less than 37% (Ministry of Transport, 2008). It is therefore difficult to apply international data about the effectiveness of safety helmets to New Zealand as there may be systematic differences between people overseas who choose to wear helmets and those in New Zealand who are legally required to use them. For example, overseas helmet wearers may be more cautious whilst cycling because they are more concerned about their safety than cyclists in New Zealand who are obliged to wear helmets under current transport laws.

Another methodological issue that makes these studies difficult to compare lies in the variability of definitions used. Most studies restrict the term “facial injury” to serious injuries such as lacerations and fractures (Worrell, 1987; Thompson *et al.*, 1999), while others have used specific scales to evaluate the severity of injuries (Yamamoto *et al.*, 2011). Several methods have also been used to classify the location of facial injuries. Some authors have recorded these injuries based on anatomical sites (Lee and Chou, 2008; Thompson *et al.*, 1999), while others have mapped them to specific facial zones (Harrison and Shepherd; 1999).

## Future research directions

There is a significant amount of heterogeneity in the population characteristics and data collection methods used in overseas studies, which makes it difficult to draw strong conclusions about the effectiveness of helmet use in preventing facial injuries. There is certainly scope for research into the impact of safety helmet legislation in New Zealand. Current research mostly pertains to the post-legislation period and is limited to common trends relating to demographics, type of fracture, mode of injury and treatment modalities (Lee and Chou, 2008). Retrospective studies comparing cycling-related facial trauma before and after legislation was introduced may be useful in providing further information preventing facial injury. One possibility for carrying out such a study includes collecting data from district health boards using a standardised classification system that accounts for both soft and hard tissue injuries in the orofacial region.

Some authors believe that safety helmets should be further developed to provide some protection to susceptible sites, such as the mandible and zygoma (Acton *et al.,* 1996; Chapman and Curran, 2004). Increasing the complexity of safety helmets, however, may result in increased weight which may discourage people from cycling activities. The effectiveness of any new helmet modification should therefore be evaluated using well-designed studies. Other preventative strategies, such as an improved cycling infrastructure, should also be explored.

## Acknowledgements

The authors thank Austin Kang for his help with preparing the colour-coded illustrations in this article.

## References

Ministry of Transport. Financial, Economic and Statistical Analysis Team. New Zealand Household Travel Survey 2009-2013. Christchurch: Ministry of Transport; 2013. 4 p.

Tin Tin S, Woodward A, Thornley S, Langley J, Rodgers A, Ameratunga S. Cyclists’ attitudes toward policies encouraging bicycle travel: findings from the Taupo Bicycle Study in New Zealand. Health Promot Int. 2010;25:54-62.

Lee KH, Chou HJ. Facial fractures in road cyclists. Aust Dent J 2008;53:246-249.

Ministry of Transport. Raising the Profile of Walking and Cycling in New Zealand. A Guide for Decision Makers. Auckland: Ministry of Transport; 2008. 14 p.

International Traffic Safety Data and Analysis Group. Road Safety Annual Report 2013. Paris: OECD International Transport Forum; 2013. 330 p.

Clarke CF. Evaluation of New Zealand's bicycle helmet law. NZ Med J. 2012:125(1349):60-9.

Kopjar B, Wickizer TM. Age gradient in the cost-effectiveness of bicycle helmets. Prev Med. 2000:30:401-6.

Robinson DL. Changes in head injury with the New Zealand bicycle helmet law. Accid Anal Prev. 2001:33:687-91.

Taylor M, Scuffham P. New Zealand bicycle helmet law—do the costs outweigh the benefits? Inj Prev. 2002:8:317-20.

Robinson, D.L. No clear evidence from countries that have enforced the wearing of helmets. BMJ. 2006:332:722-725.

Antoun J, Lee K. Sports-Related Maxillofacial Fractures Over an 11-Year Period. J Oral Maxillofac Surg. 2008:66:504-508.

Qing-Bin Z, Zhao-Qiang Z, Dan C, Yan Z. Epidemiology of maxillofacial injury in children under 15 years of age in southern China. Oral Surg Oral Med Oral Pathol Oral Radiol. 2013:115:436-41.

Thompson DC, Rivara F, Thompson R. Helmets for preventing head and facial injuries in bicyclists. Cochrane Database Syst Rev 1999:4:1-31.

Lindqvist C, Sorsa S, Hykras T, Santavirta S. Maxillofacial fractures sustained in bicycle accidents. Int J Oral Maxillofac Surg 1986:15:12-18.

Boffano P, Roccia F, Gallesio C, Karagozoglu KH, Forouzanfar T. Bicycle-related maxillofacial injuries: a double-center study. Oral Surg Oral Med Oral Pathol Oral Radiol. 2013:116:275-80.

Yamamoto K, Horita S, Matsusue Y, Murakami K, Sugiura T, Kirita T. Maxillofacial Fractures Sustained in Bicycle Accidents. J Oral Maxillofac Surg. 2011:69:155-160.

Syed SH, Willing R, Jenkyn TR, Yazdani A. Video analysis of the biomechanics of a bicycle accident resulting in significant facial fractures. J Craniofac Surg. 2013:24:2023-9.

McDermott FT, Lane JC, Brazenore GA, Debney EA. The effectiveness of bicyclist helmets: a study of 1710 casualties. J Trauma. 1993:34:834–45.

Thomas S, Acton C, Nixon J, Battistutta D, Pitt WR, Clark R. Effectiveness of bicycle helmets in preventing head injury in children. Br Med J. 1994:308:173–6.

Maimaris C, Summers CL, Browning C, Palmer CR. Injury patterns in cyclists attending an accident and emergency department: a comparison of helmet wearers and non-wearers. Br Med J. 1994:308:1537–40.

Thompson DC, Rivara FP, Thompson RS. Effectiveness of bicycle safety helmets in preventing head injuries: a case-control study. JAMA. 1996:276:1968–73.

Hansen P, Scuffham PA.The cost-effectiveness of compulsory bicycle helmets in New Zealand. Aust J Public Health. 1995:19:450-4.

Thompson DC, Nunn ME, Thompson RS, Rivara FP. Effectiveness of bicycle safety helmets in preventing serious facial injury. JAMA. 1996:276:1974–5.

Tin Tin S, Woodward A, Ameratunga S. Incidence, risk, and protective factors of bicycle crashes: findings from a prospective cohort study in New Zealand. Prev Med. 2013:57:152-61.

Romanow NR, Hagel BE, Williamson J, Rowe BH. Cyclist head and facial injury risk in relation to helmet fit: a case-control study. Chronic Dis Inj Can. 2014:34:1-7.

Harrison MG, Shepherd JP. The circumstances and scope for prevention of maxillofacial injuries in cyclists. J R Coll Surg Edinb. 1999:44: 82-86.

Karkhaneh M, Rowe BH, Saunders LD, Voaklander D, Hagel B. Bicycle helmet use after the introduction of all ages helmet legislation in an urban community in Alberta, Canada. Can J Public Health. 2011:102:134-8.

Hansen KS, Engesaeter LB, Viste A. Protective Effect of Different Types of Bicycle Helmets. Traffic Inj Prev. 2003:4:285-90.

Scuffham PA, Langley JD. Trends in cycle injury in New Zealand under voluntary helmet use. Accid Anal Prev. 1997:29:1-9.

Povey LJ, Frith WJ, Graham PG. Cycle helmet effectiveness in New Zealand. Accid Anal Prev. 1999: 31:763-770.

Moyes SA. Changing pattern of child bicycle injury in the Bay of Plenty, New Zealand. J Paediatr Child Health. 2007:43:486-8.

Scuffham P, Alsop J, Cryer C, Langley JD. Head injuries to bicyclists and the New Zealand bicycle helmet law. Accid Anal Prev. 2000:32:565-73.

Adams J, Hillman M. Bicycle helmets: risk taking is influenced by people's perception of safety and danger. Br Med J. 2001: 322:1063-1064.

Coggan CA, Disley B, Patterson P, Norton R. Risk-taking behaviours in a sample of New Zealand adolescents. Aust NZ J Public Health. 1997:21:455-61.

Tin Tin S, Woodward A, Ameratunga S. What influences the association between previous and future crashes among cyclists? A propensity score analysis. PLoS One. 2014:9:e87633.

Worrell J. Head injuries in pedal cyclists: how much will protection help? Injury. 1987:18:5-6.

Acton CH, Nixon JW, Clark RC. Bicycle riding and oral/maxillofacial trauma in young children. Med J Aust. 1996:165:249-51.

Chapman HR, Curran AL. Bicycle helmets—does the dental profession have a role in promoting their use? Br Dent J 2004:196:555-60.

## Authors:

*Grace AL Nichols*[1,2] *BDS (corresponding author grace.nichols1@gmail.com)*
*Joseph S Antoun*[1] *BDS DClinDent*
*Azza H Al-Ani*[1] *BDS DClinDent*
*Darryl C Tong*[1] *MSD, PhD*

[1] Sir John Walsh Research Institute, University of Otago, PO Box 647, Dunedin 9054, New Zealand
[2] Hospital Dental, Christchurch Hospital, Canterbury District Health Board, Christchurch, New Zealand