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Changes in the pattern of paediatric bicycle injuries in relation to helmet use 1980-2014

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ABSTRACT

INTRODUCTION:

This study aimed to describe long-term changes in injury pattern in bicycle accidents among children in relation to the increasing use of bicycle helmets.

METHODS:

This was a descriptive register study of all children aged 6-14 years with injuries from bicycle accidents who were treated at a Danish university hospital in the 1980-2014 period. Diagnoses and helmet use were analysed and stratified by gender and age group. Diagnoses were grouped into head injuries, severe head injuries, facial injuries, bone fractures, spinal injuries and internal injuries. We defined severe head injuries as skull fractures and intracranial injuries including concussions, haemorrhages and lacerations.

RESULTS:

We included 13,294 children, 58.7% were boys. From 1980-1984 to 2010-2014, the use of helmets increased from 0% to 49.9% in boys and from 0% to 57.1% in girls. The proportion of boys and girls with head injuries decreased from 31.3% to 17.4% and from 29.6% to 10.1%, respectively. A similar reduction was found in the proportion of children with severe head injuries. In the study period, the proportion of children with facial injuries, fractures, spinal injuries and internal injuries in trunk remained unchanged. Eighteen children died from their injuries, none of whom wore a helmet.

CONCLUSIONS:

In the study period, the proportion of head and severe head injuries decreased by 50% along with an increase from 0% to 50% in helmet use. The proportion of facial injuries, spinal injuries, bone fractures and injuries to the internal organs remained unchanged.

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Bicycles are widely used as a mode of transportation to school and for recreational activities among children in many countries. Learning to ride a two-wheeled bicycle is an important milestone in a child's life. Unfortunately, bicycling is also a common cause of injury, with children aged 5-14 years having the highest injury rate [1]. Head injuries are a particular risk and are the most common cause of serious disability and death from bicycle accidents [2]. Among Danish schoolchildren, the use of bicycle helmets has increased from 33% in 2004 to 76% in 2018 [3].

International studies underscore the efficacy of helmets in reducing head injury among both children and adults [4-9]. A meta-analysis found helmet use to be associated with a reduction in facial injury (33%), head injury (51%), serious head injury (69%) and fatal head injury (65%) [10]. Furthermore, a Cochrane review has shown that the incidence of serious head injuries in bicycle accidents can be reduced by 65% by wearing a bicycle helmet [11]. Laboratory studies with biomechanical testing have also shown the importance of bicycle helmet use [12]. However, there are very few long-term studies describing the changes in

injury patterns in bicycle accidents along with the increasing use of bicycle helmet in children.

The purpose of this study was to describe the long-term changes in injury patterns in bicycle accidents among children in relation to the increased use of bicycle helmets.

METHODS

This study was a descriptive register study. The cases included are children aged 6-14 years who were treated at the Emergency Department (ED) at Odense University Hospital (OUH) in Denmark after sustaining a bicycle-related injury in the 1980-2014 period. A bicycle-related injury was defined as any injury sustained while participating in bicycle-related activities as an operator or passenger. In cases of more than one contact for the same injury, only the first contact was included.

The OUH is located in the Odense Municipality in the Region of Southern Denmark on the Island of Funen. The municipality has a population of approximately 200,000 inhabitants. Of these, 19,000 are children in the 6-14-year age range. The ED at OUH serves both Odense Municipality and neighbouring municipalities. The university level trauma centre at OUH serves the entire Region of Southern Denmark with a population of one million. Odense Municipality has 545 km of bicycle paths. The municipality had no helmet law during the entire study period.

When patients presented in the ED after a bicycle-related injury, trained staff registered age, sex, injuries sustained and whether a bicycle helmet was used or not. Due to a systematic error in the 1995 data, all data from 1995 were excluded from the study.

All diagnoses were coded according to the ICD system. For the 1980-1993 study period; the ICD8 was used and for the 1994-2014 study period, the newer ICD10 was used. Diagnoses were grouped into head injuries, severe head injuries, facial injuries, bone fractures, spinal injuries and internal injuries in the thorax/abdomen. We defined head injuries as all injuries involving the head, excluding injuries to the face and ears. We defined severe head injuries as skull fractures and intracranial injuries including concussions, cerebral or intracranial haemorrhages and lacerations of the brain.

The time trend of injury patterns in association with the use of bicycle helmet was analysed in five-year groups stratified by age and gender. Due to the exclusion of data for 1995, a single four-year group (1996-1999) was defined. The analyses were made using Epidata Analysis. Non-parametric statistics were used in all analyses. p-values < 0.05 were considered significant.

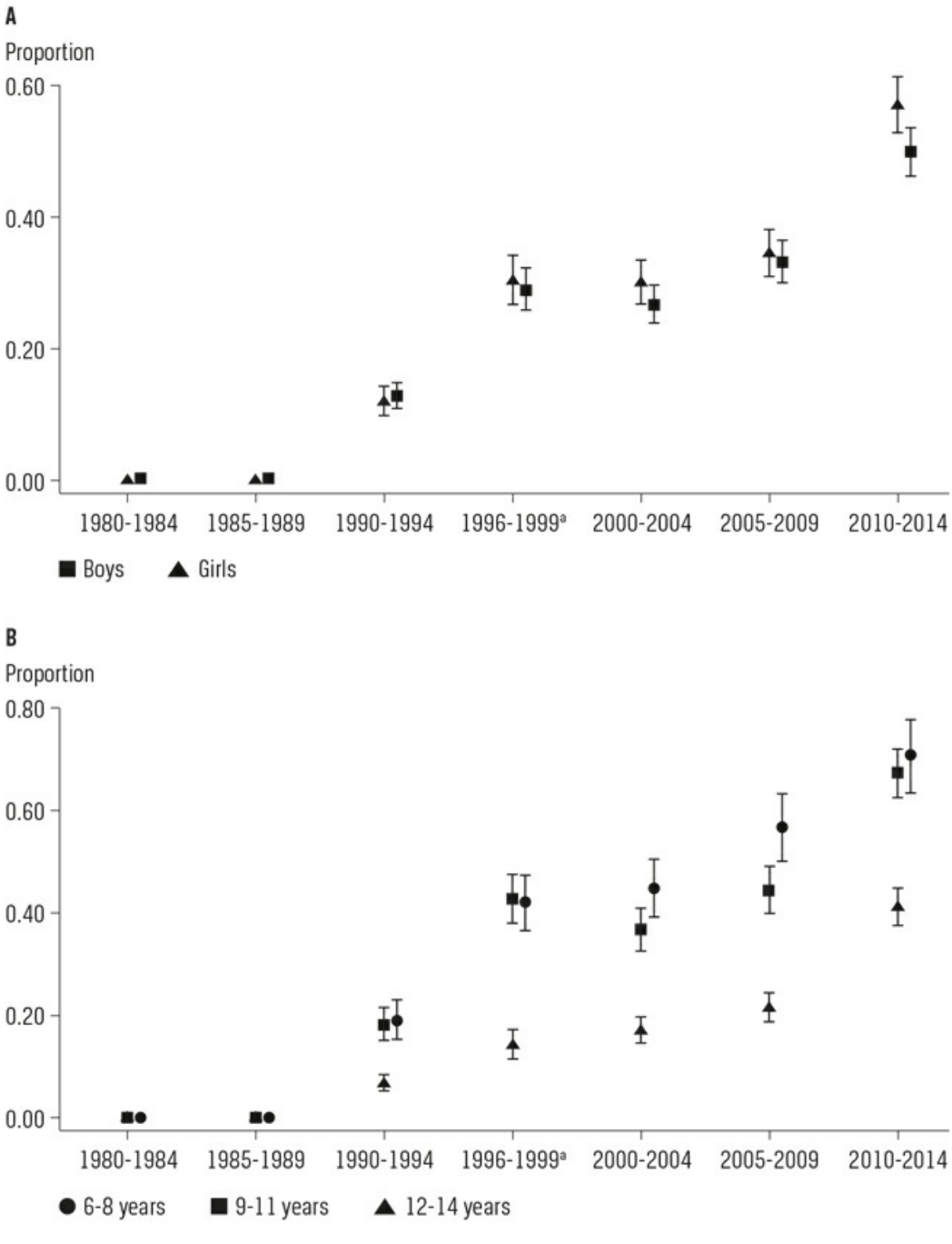
Trial registration: not relevant.

RESULTS

In the study period, 13,294 children aged 6-14 years were treated at the ED of OUH with injuries due to bicycle accidents. There were 5,491 (41.3%) girls and 7,803 (58.7%) boys. The median age was 11 years for both boys and girls alike. Overall, 24.2% had head injuries, 4.1% had severe head injuries, 9.5% had facial injuries, 17.7% had limb fractures, 0.04% had spinal injuries and 0.07% had internal trunk injuries. Three fourths of the accidents were solo accidents, 11% were hit by another bicyclist, 9% were hit by a four-wheeled vehicle and 1% were hit by a two-wheeled vehicle. In 4% of the cases, the counterpart was unspecified. The distribution by trauma mechanism remained unchanged in the study period.

A total of 1,067 (19.4%) girls and 1,288 (16.5%) boys wore a bicycle helmet at the time of their accident. From 1980-1984 to 2010-2014, this proportion increased from 0% to 57.1% (95% confidence interval (CI): 52.8-61.3%) among girls and from 0% to 49.9% (95% CI: 46.3-53.6%) among boys (**Figure 1**). From 1980-1984 to 2010-2014, the proportions increased from 0% to 70.9% (95% CI: 63.3-77.7%), 67.3% (95% CI: 62.5-72.0%) and 41.1% (95% CI: 37.5-44.8%) in the age groups 6-8, 9-11, and 12-14 years, respectively (Figure 1).

FIGURE 1 / The proportion of all injured children treated at an emergency department who were wearing helmet at the time of their bicycle accident, stratified by gender (A) and age groups (B).

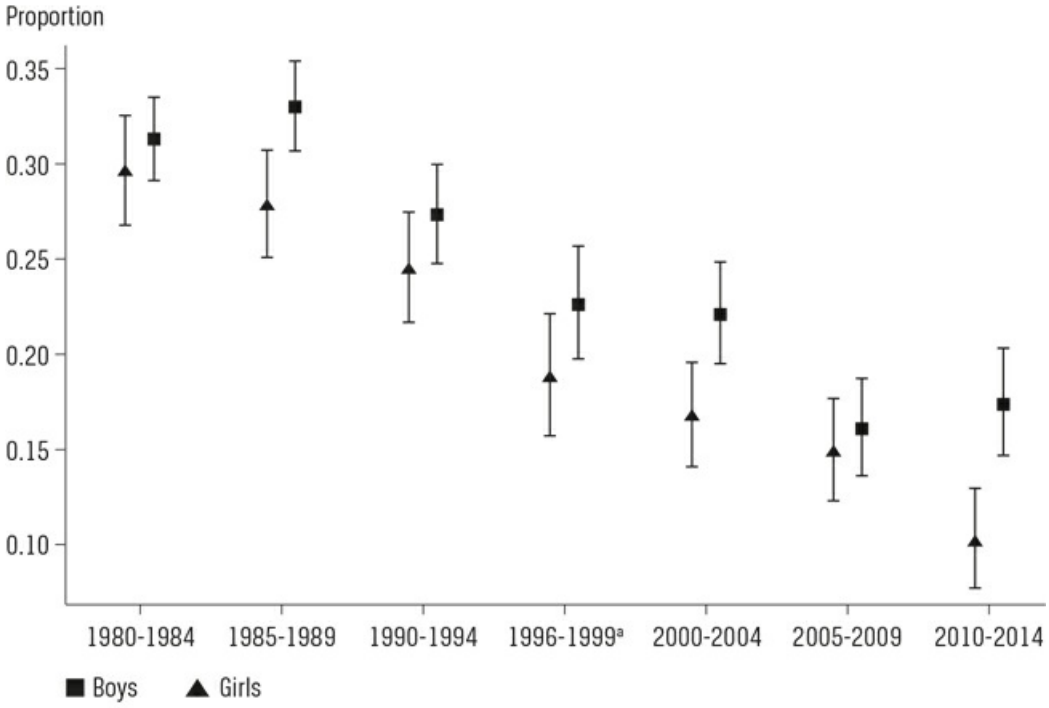


a) Due to a systematic error in the 1995 data, all data from 1995 were excluded from the study.

From 1980-1984 to 2010-2014, there was a gradual decrease in head injuries from 31.3% (95% CI: 29.1-33.5%) to 17.4% (95% CI: 14.7-20.3%) in boys and from 29.6% (95% CI: 26.8-32.5%) to 10.1% (95% CI: 7.7-13.0%) in girls (**Figure 2**). Stratified by age groups, the proportion of head

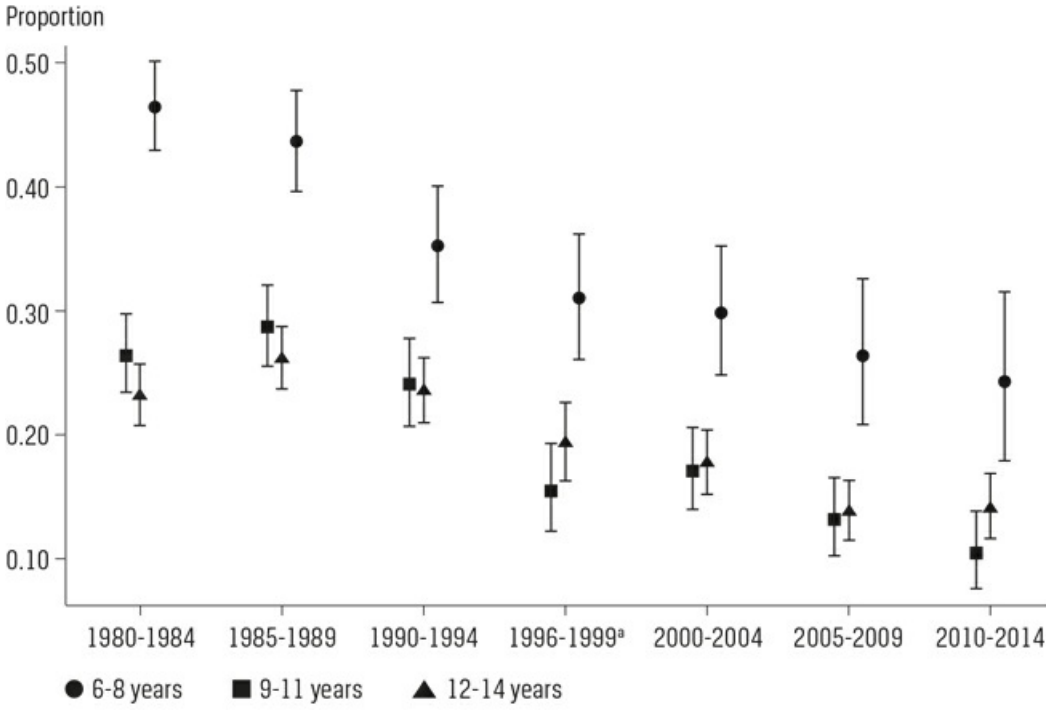
injuries decreased significantly from 46.5% (95% CI: 43.0-50.0%) to 24.4% (95% CI: 17.9-31.5%) in the age group 6-8 years, from 26.4% (95% CI: 23.5-29.5%) to 10.5% (95% CI: 7.6-13.9%) in the age group 9-11 years, and from 23.2% (95% CI: 20.7-25.7%) to 14.1% (95% CI: 11.7-16.9%) in the age group 12-15 years (**Figure 3**).

FIGURE 2 / The proportion of children with head injuries among all children treated at the emergency department for bicycle injuries in the study period, stratified by gender. Head injuries are defined as all injuries involving the head excluding injuries to the face and ears.



a) Due to a systematic error in the 1995 data, all data from 1995 were excluded from the study.

FIGURE 3 / The proportion of children with head injuries among all children treated at the emergency department for bicycle injuries in the study period, stratified by age groups. Head injuries are defined as all injuries involving the head excluding injuries to the face and ears.



a) Due to a systematic error in the 1995 data, all data from 1995 were excluded from the study.

In the same period, the proportion of children with severe head injuries decreased from 5.9% (95% CI: 4.8-7.1%) to 3.8% (95% CI: 2.5-5.5%) in boys and from 6.8% (95% CI: 5.3-8.6%) to 2.6% (95% CI: 1.5-4.4%) in girls. Similarly, we found a decrease in the proportion of severe head injuries in all age groups. From 8.1% (95% CI: 6.3-10.3%) to 4.2% (95% CI: 1.7-8.6%) in the age groups 6-8 years (trend test, p = 0.014), from 5.1% (95% CI: 3.7-8.6%) to 2.8% (95% CI: 1.4-5.0%) in the age group 9-11 years, and from 4.7% (95% CI: 3.5-6.1%) to 3.2% (95% CI: 2.0-4.7%) in the age group 12-15 years. However, the change was not statistically significant among the eldest.

Table 1 shows the proportion of children with head injuries, severe head injuries and helmet use including odds ratios (ORs). Overall, the proportions of head injuries in the group of children not wearing helmets were twice the proportions found among children wearing helmets, corresponding to ORs between 0.33 and 0.43. We found a similar pattern in the proportions of severe head injuries (OR: 0.47-0.68).

TABLE 1 / The proportion of head injuries and severe head injuries and helmet use including odds ratios (OR) (95% confidence interval (CI)).

	Head injury			Severe head injury		
	helmet, n (%)	no helmet, n (%)	OR (95% CI)	helmet, n (%)	no helmet, n (%)	OR (95% CI)
Gender						
Boys	188 (14.6)	1,847 (28.4)	0.43 (0.37-0.51)	40 (3.1)	295 (4.5)	0.68 (0.48-0.95)
Girls	129 (12.6)	1,062 (24.0)	0.44 (0.36-0.53)	25 (2.3)	190 (4.3)	0.53 (0.35-0.81)
Age group, yrs						
5-8	152 (24.9)	913 (41.1)	0.47 (0.39-0.58)	26 (4.3)	137 (6.2)	0.68 (0.44-1.03)
9-11	94 (9.8)	748 (24.6)	0.33 (0.26-0.42)	20 (2.1)	132 (4.3)	0.47 (0.29-0.75)
12-14	71 (9.1)	1,248 (22.0)	0.35 (0.28-0.46)	19 (2.4)	216 (3.8)	0.63 (0.39-0.99)
Total	317 (13.5)	2,909 (26.6)	0.43 (0.38-0.49)	65 (2.8)	485 (4.4)	0.61 (0.47-0.80)

The proportion of children with limb fractures, facial injuries, spinal injuries and injuries to the internal organs in the thorax and abdomen remained unchanged in the study period (trend test, p = 0.49, p = 0.31, p = 0.32, and p = 0.37, respectively).

In the study period, 18 (0.001%) children died due to their injuries. Thirteen (72%) were boys and five (28%) were girls. The median age was 11 years (range: 7-14 years) for both boy and girls. All deceased children had severe head injuries and none of them wore a helmet at the time of their accident.

DISCUSSION

The proportion of both head injuries and severe head injuries from bicycle accidents decreased by 50% in the study period in both boys and girls. In the same period, the use of bicycle helmets among the injured children increased from 0% to approx. 50%. These changes were observed in all age groups. This important benefit from wearing bicycle helmets has also been shown in numerous previous studies, a systematic review and meta-analysis and a Cochrane review [4-11]. The increase in helmet use may be a result of an increased awareness of the benefits of helmet use. Several nationwide campaigns have been conducted, and a wide variety of bicycle helmets is easily obtained. The increase in helmet use was highest among girls and in the youngest age group. Similarly, the decrease in both head injuries and severe head injuries was highest in the youngest girls. Previous studies have also documented the highest proportion of helmet use among girls and young school children [3, 13].

Our study indicates a 50% reduction in head injuries and severe head injuries when using bicycle helmets. This is comparable to reports from other studies [5, 7]. To further illustrate

the significant benefit of helmet use, none of the deceased children in our study wore a helmet at the time of injury and all died from severe head injuries, which is consistent with previous studies [5, 8].

We found very few spinal injuries and injuries involving internal organs. Furthermore, the proportions of children with facial injuries, spinal injuries, bone fractures and internal organ injuries remained unchanged in the study period. Previous studies have shown a divergent effect of bicycle helmets on facial injuries [6, 14]. A meta-analysis found helmet use to be associated with a 33% reduction in facial injuries [10].

In our study, boys and girls were more equally represented than in other studies [4, 8, 9]. This may be explained by the wide use of bicycles among both boys and girls, not only as a recreational use but also as a mean of transportation for school and leisure activities. Other cultural differences may also have influenced this result [15].

The present study is a register study and may be affected by information bias. When interviewing the children and their parents in the ED, they may wrongfully have stated that they wore a bicycle helmet even though this was not the case. Therefore, there may be an overrepresentation of helmet use. On the other hand, since there is no law in Denmark on the use of bicycle helmets, the incentive to do so is not very strong.

During the study period, the diagnostic coding changed. In 1994, the ED introduced the new ICD10 coding system in replacement of the previous ICD8. This may have led to an error in the data due to changes in the coding practice of diagnoses. However, a detailed analysis of the coding practice before and after the change in ICD version has been conducted. Due to a systematic error in the 1995 data, these data were excluded from the study. Changes in the access to CT may have changed in the study period, influencing the diagnostic criteria of severe head injuries, which most likely has led to diagnosing of an increasing number of severe head injuries during the study period. Unfortunately, we have no reliable information about changes in CT usage. The cardinal challenge in this register study was to identify the relationship between injuries and helmet use. Even though there is a decrease in the proportion of head injuries, which is concurrent with the increase in helmet use, other factors may influence the results. The design of roads and the increasing number of bicycle paths separating bicyclists from motor vehicles, the designs of cars with deformation zones and the introduction of emergency brake assistants, and the use of additional mirrors on trucks may all reduce the proportion of head injuries.

The strength of this study is the wide time span and the completeness of data. However, the number of EDs on the Island of Funen changed during the study period. In the 1980s, there were five EDs with 24-hour access. From 2014 onwards, there has been only one large ED left with 24-hour access. This has increased the number of children treated at the ED at OUH during the study period. However, we have no reason to believe that this has changed the proportion of head injuries and severe head injuries.

Based on the data of this study and numerous other studies, we strongly recommend the use of bicycle helmets among children. Through the years, compelling evidence has emerged regarding the decrease in serious head injury and death owing to the use of bicycle helmets. This study confirms this. Furthermore, in our study, the low proportion of children with potentially severe and life-threatening injuries to the spine and internal organs remains low. Therefore, future effort should concentrate on identifying specific groups of children among whom changes in the attitudes regarding voluntary helmets use may reduce even further the occurrence of severe head trauma and death. Studies have revealed that both school and parents are important factors [7, 15]. Ong et al. found that the greater influence on children's attitude to helmet use was the parental rules, indicating the importance of early implementation of helmet rules in order to establish habit [7]. In our study, the same subpopulation of children (age group 6-8 years in 1996-1999, 9-11 years in 2000-2004, and 12-14 years in 2005-2009) saw a decrease in helmet use. Children aged 12-14 years seem to be the most challenging age group when it comes to obtaining and retaining good helmet-wearing habits. We believe that future campaigns should primarily be directed specifically at the older children and their parents. Emphasis should also be placed on the correct use and discarding of damaged bicycle helmets. Ideally, a bicycle helmet should be efficient, easy to fit correctly and inexpensive. Since the use of bicycle helmets is still relatively low, it is fundamental to obtain a higher degree of usage.

The prevention of serious bicycle injuries cannot be accomplished through helmet use alone. While previous studies examining the effect of helmet legislation on bicycle-related injuries showed mixed results, a more recent meta-analysis showed a reduction in both head injury and severe head injury [9, 16-18]. A comprehensive approach that comprises both education and awareness of ongoing enforcement of helmet legislation is associated with long-term sustained helmet use rates [19].

CONCLUSIONS

The proportion of both head and severe head injuries decreased by 50% among both boys and girls as helmet use increased from 0% to 50%. The proportion of facial injuries, spinal injuries, bone fractures and injuries to the internal organs remained unchanged. Among those who died, none wore a helmet at the time of their injury.

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