Health and safety assessment of state bicycle helmets laws in the USA

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Abstract
There are more than 60 million children under 16 years of age in the USA and about half have been subjected to state bicycle helmet laws. Survey data, 1998 to 2007, shows cycling reduced by 29.9% for 7-11 year age group. This assessment focuses mainly on fatality and health data and estimates the outcome. The findings show that helmet laws can result in 120 times more harm than the intended good and helmet promotion 12 times more harm. States with helmet laws, compared to those without, did not show significant improvement. It is estimated that between 1020 - 2040 premature deaths per year will occur due to helmet laws.

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Introduction

America has a population of approximately 300 million people. In 2008 there were 12.2 road deaths per 100,000 people or 122 per million people. In total 37261 people died on the roads.[1] For bicyclists the total was 716 deaths, including 95 below 16 years of age (approximately 1.5 per million population —lower than the rate for all cyclists, 2.3 per million population). State bicycle helmet laws have many issues, e.g. inconvenience, reduced enjoyment, safety, reduced number of people cycling, legal aspects and health. This assessment considers the issues and balances the evidence. As background information to understanding the helmet issue and topic, suggested reading is 'Bicycle Helmets: A Scientific Evaluation' by Curnow[2] and 'Cycling and Health'.[3]

Method
Several aspects are considered in assessing helmet laws, changes to fatality and injury rates, changes in cycling activity, road safety trends and wider social, legal and health implications. Grouping the fatality data for child cyclist, for states with helmet legislation compared to states without legislation, is evaluated to see if any positive aspects can be detected. The pedestrian data provides a guide to outdoor activity levels and also changes to the level of risk on the roads and any population changes that may occur. Changes to the level of cycling activity allow further comparisons to be made. Reportedly, annual data on statewide bicycle injuries do not exists but consideration is provided based on a number of reports. Data on the number of people cycling, hours of riding, miles covered, all vary substantially with survey methods, e.g. one report documents 85.3 million cyclists[4] and another refers to 80.6 million cyclists.[5] Consideration is given to improving safety for cyclists and all road users.

Fatality rate assessments, in 3 parts

Part 1 - All age assessment
One simple approach to assessing helmets is to compare changes to the number of pedestrians and cyclists deaths[6] as helmet use increases. If helmets provide a major benefit then a lower proportion of cyclist deaths compared to pedestrians should be the end result. About 90 percent of the cyclist deaths involved motor vehicles.[7]
Table 1 below, for the whole of the USA, indicates no real benefit in reduced fatalities from helmet promotion during the 1990's and into the early 2000's.

Table 1 Fatality data

All age groups	Cyclists – C	Pedestrians – P	T1-C/P
1986	941	6779	0.139
1987	948	6745	0.140
1988	911	6870	0.132
1989	832	6556	0.127
1990	859	6482	0.132
Average 86-90	898	6686	0.134
2004	725	4641	0.156
2005	784	4881	0.160
2006	773	4784	0.161
2007	698	4654	0.145
2008	716	4378	0.163
Av. 04-08	740	4688	0.157

Pedestrians had on average a 30% reduction, 6686 to 4688. For cyclists to follow the same improvement they would have to average 629, whereas they actually averaged 740, or 17.6% higher than the trend. The number of people cycling may have increased but also the number of pedestrians will have increased, e.g. in 2000 the USA population was about 281 million and by 2008, roughly 304 million. Sixty-one percent of bicyclist deaths in 2008 occurred on major roads other than interstates and freeways, and 35 percent occurred on minor roads.[8] Twenty-four percent of bicyclists killed in 2006 had blood alcohol concentrations (BACs) at or above 0.08 percent. This percentage is one-third higher than in 1982. Crocker et al[9] reported "Alcohol use leads to a host of unsafe bicycling practices, increased head and brain injuries, and costs to the cyclist and community." Alcohol impaired riders rarely wore helmets.

Part 2
Cyclist fatality assessment, 0-15 year age group
Table 2 below provides cyclist and pedestrian data,[10] 1991 to 2008, for all states.

Table 2, Fatality data, 0- 15 age group

	Cyclists - C	Pedestrians - P	T2-C/P
1991	307	857	0.358
1992	303	761	0.398
1993	310	818	0.378
1994	299	806	0.371
1995	280	754	0.371
1996	248	715	0.346
1997	250	644	0.388
1998	230	580	0.396
1999	214	567	0.377
2000	190	517	0.367
2001	193	484	0.398
2002	155	434	0.357
2003	145	433	0.334
2004	149	393	0.379
2005	144	388	0.371
2006	110	369	0.298
2007	107	354	0.302
2008	95	316	0.301

Data from 1991 shows no improvement for cyclists compared to pedestrians until 2006, when the ratio (T2-C/P) reduced from 0.371 to 0.298, a drop of effectively 20% in one year and continuing at the reduced level into 2007 and 2008. Between 1991 and 2005 when helmets were being promoted and legislation introduced, there was little change in the ratio of cyclist to pedestrian deaths. The most likely explanation for the drop in 2006 would be that some children have been discouraged from cycling. From 2004 to 2008, the number of deaths to motor vehicle occupants reduced from 33134 to 26689, a fall of 19% and this may reflect improved road safety behavior. Cycle training programs for children also developed during the 1990's and these could have improved safety.

Cycling can show substantial reductions in fatalities when changes occur to the level of road safety plus changes in the level of cycling activity. Trends in the UK for child cyclist fatalities, where fewer than 20% of children wear helmets, shows what can occur in Table 3. The UK had a higher percentage reduction than the USA, even with 20 states passing helmet laws.

Table 3 - UK Child cyclist fatality data (DfT data)

	1981-5 average	1994-8 average	2003
0-4	2	1	1
5-7	8	5	1
8-11	30	13	3
12-15	58	24	13
Total <16	98	43	18

Reduced cycling activity
USA survey data on the level of cycling activity appears to be less substantial than it could be. Data from '2007 Youth Participation in Selected Sports with Comparisons to 1998' shows reduced cycling activity from 1998 to 2007.[11] Participated (in thousands) for seven (7) years of age and older is shown below;

	YEAR	TOTAL	Change vs 1998	Total 7-11	Change vs 1998	Total 12-17	Change vs 1998
Bicycle Riding	1998	43,535		10,055		7,844	
Bicycle Riding	2007	37,405	-14.1%	7,046	-29.9%	6,518	-16.9%

The data shows a drop of 6.13 million and a significant reduction in cycling for the age group 7-17 years occurred between 1998 and 2007. Estimating a 20% reduction for the age group 0-15 years and relating to data from Table 2, the ratio for 2007 would change from 0.302 to 0.378, indicating no improvement for cyclists compared to pedestrians. Grant and Rutner[12] assessment of helmet legislation mentions fatalities reduce by 15% in the long term, less in the short term, but they commented "there must be other time-varying factors that influence juvenile bicycling fatalities more than helmet laws do." It referred to a 21% reduction in bicycle use associated with a 12% reduction in fatalities. Carpenter and Stehr[13] found a reduction in cycling of 4% -5% occurred due to legislation from 1991 to 2005 and also reported helmet laws reduce fatalities by 19%, however they mention "Although we estimate that bicycling participation fell by about 5 percent, it is likely that overall bicycling miles traveled fell even more". Data provided here from Table 1 and 2 does not support these findings of helmet use appreciably reducing fatalities. The 2007 Youth Participation in Selected Sports information suggests more of a reduction in later years and this could explain the "15% reduction in the long term" and also the drop in Table 2 of the proportion for cyclist to pedestrian ratio, 0.371 in 2005 to 0.298 in 2006. The 15% and 19% fatality reduction estimates are probably derived at by underestimating the reduction in cycling combined with the limitations of survey data.

In 2008, a total of 1,347 children age 14 and younger were killed in motor vehicle traffic crashes. Of those 1,347 fatalities, 216 (16%) occurred in alcohol-impaired-driving crashes. Out of those 216 deaths, 99 (46%) were occupants of a vehicle with a driver who had a BAC level of .08 or higher. Another 34 children were pedestrians or pedalcyclists who were struck by drivers with a BAC of .08 or higher.[14]

Part 3

Cyclist fatality assessment, 0-15 year age group, compares states with helmet laws to those without

States with helmet legislation tend to be coastal and have higher levels of road safety, e.g. in 2000 the states with helmet laws averaged 13.8 fatalities per 100,000 population compared to 16.3 for states without helmet legislation. States without helmet legislation tend to be more rural and this would probably affect road safety and cycling levels. Comparing data for states with legislation, see Appendix 1, to those without legislation may show changes. Cyclist fatality data for 1991 is divided into two groups, those states with legislation and those without. A comparison of data, 1991 with 2007, divided into the same two groups, provides a guide as to whether helmet laws have provided any benefit, see Table 4.

Table 4

Cyclist 0-15 year age group

	1991 fatalities	2007 fatalities	% reduction
Helmet law states	157	57	65.7%
Non-helmet law states	150	50	66.7%

The above data indicates almost identical reduction in cyclist fatalities for both groups. Actual percentage reductions in fatalities were 66.7% compared to 65.7%. It is probably the case that helmets have not made a significant difference to saving lives but have discouraged some younger riders from cycling. The BMA concluded in 2008[15] that for fatal accidents, the force of impact in such instances is considered so significant that most protection would fail. There are incidents of deaths to children due to strangulation by helmet straps. The BHSI[16] state "Children should not wear helmets on playgrounds or when

climbing trees. The helmet can snag and the strap can asphyxiate them. Several deaths have been recorded, and more close calls." USA reports claim fewer helmeted deaths compared to non-helmeted and this suggests a benefit. Cyclehelmets.org provides details to suggest the proportion stated to be wearing helmets is below their actual number.[17] There can also be a major difference in the risk factor for various types of cyclist, e.g. a factor of 10 to1 can occur. A cyclist trying to be safe can be much different to a cyclist taking high risks in the way they ride. Helmeted cyclists often use hi-visibility vests, lights and they may be less inclined to have been drinking and the fatality data may reflect substantially more than just helmet use.

Injury data and concerns

NEISS and Consumer Product Safety Commission data on bicyclist injuries has been published on the cyclehelmets.org web site, which may not indicate significant improvement, due to helmet use.[18] The CPSC changed their model for calculating total estimates in the mid-late 1990's and this could also have an affect. Erke and Elvik[19] (Norwegian researchers) 2007 stated: "There is evidence of increased accident risk per cycling-km for cyclists wearing a helmet. In Australia and New Zealand, the increase is estimated to be around 14 per cent." Australian data strongly indicated helmet use increased the accident rate for younger cyclists.[20] Data from Seattle also raised concerns that the accident rate may be higher for helmet wearers.[21] Additional concerns arise because helmet use may increase injury severity. Across Canada, cyclist's the length of stay in hospital for head injuries increased from 4.3 days to 6.9 days.[22] Reported in October 2009 "Bicycle injuries in the US have become more severe and there has been a marked increase in chest and stomach injuries."[23] Also reported form Israel, "Bicycle-related injuries in children: Disturbing profile of a growing problem (including more severe injuries)."[24] USA information suggests severe head injuries have increased from 1980 to 1995, but if this is cycling related is not clear and needs further investigation.[25]

Health assessment

Moderate cycling has many physical and mental benefits (BMA 1992[26]) by reducing the risk of developing heart disease,[27] diabetes, high blood pressure, colon cancer and depression, and helping to control weight and increase fitness. Dr Hillman from the UK's Policy Studies Institute calculated the life years gained by cycling outweigh life years lost in accidents by a factor of 20 to 1.[28] Bupa reports,[29] "everyday cycling, where the exercise leaves you breathing heavily but not being out of breath, is an effective and enjoyable form of aerobic exercise. This is the type of exercise that is most effective at promoting good health." Population studies from Denmark, Finland and China find an association between cycling, lower rates of obesity and reduced mortality and cardiovascular risk.[30]

Of concern to Americans is the high prevalence of people with risk factors such as obesity and insufficient exercise, which are associated with chronic diseases such as heart disease, diabetes, and hypertension[31].[32] Many people can become physically active for short periods of time but this is not typical of cyclists who generally cycle for years. One likely contributory cause for the increase in obesity, is the promotion of helmets and the added legal requirements, which discourage cycling at a time when encouraging more exercise and cycling is badly needed. As a guide to costs, from 1999 to 2002, the average annual cost of non-fatal bicycle injuries in children and youth age 0 to 19 was $3.6 billion.[33] In 2000, the total cost of obesity in the United States was estimated to be $117 billion.[34] Cost of diabetes in 2007 was estimated at $174 billion, 2 million adolescents (or 1 in 6 overweight adolescents) aged 12-19 have pre-diabetes[35] (Diabetes causes, 12,000 to 24,000 new cases of blindness each year, 178,689 people with end-stage kidney disease due to diabetes were living on chronic dialysis or with a kidney transplant, 60% to 70% of people with diabetes have mild to severe forms of nervous system damage, about 71,000 lower-limb amputations.). The American Heart Association[36] estimates all cardiovascular diseases together are projected to cost $475.3 billion in 2009.

The percentage of overweight young people in the USA has increased during the time of helmet promotion. In 1990 10% of 2-19 year age group were overweight, by 2000 this had increased to about 14.8% and by 2005 increased again to about 16.3%.[37] Cleave et al reported chronic health conditions, including obesity, among children and youth had increased from 11.2% to 25.2% between 1988 and 2006.[38] In 1988 about 1 in 9 young people had major health concerns and today the figure is about 1 in 4. Rodgers referring to 1991 mentions "riders under age 15 reportedly ride about 300 hours per year" and "children under age 10 ride primarily on sidewalks, playgrounds, and neighborhood streets"(ref 7 Rodgers, page 4/169). According to the CDC "Children and adolescents should do 60 minutes (1 hour) or more of physical activity each day."[39] This information indicates cycling was a main physical activity for many children, providing over 80% of their exercise requirements. Children who cycle to school are more physically active and fit than those who use other modes of transport, according the journal of the American College of Sports Medicine.[40] Boys who cycled to school were 30 percent more likely to be fit, girls who cycled to school were seven times more likely to reach the minimum fitness standard than girls who used motorized transport. The findings are based on a study of 6,000 children, ages 10 to 16, from the eastern region of England.

In 2006, total road deaths were 42642, including 773 cyclists. For the death of each cyclist there are approximately 120,000 obese people[41] and 30,000 with diabetes.[42] Survey information indicates that cycling may have been discouraged by between 4% and 29.9% and generally this is without strict enforcement of helmets laws. The 2007 Youth Participation in Selected Sports survey shows that cycling has reduced from first place in 1998 to second place, behind bowling by 2007. One activity can be included in day-to-day travel, to school, shops etc and requires little expense and the other may require transport to access, expense and time to be made available. The Telegraph reported "Unfit, lazy children are six times more likely to develop early signs of heart disease than those who are active and take exercise, scientists have warned. For the first time, experts have established that activity levels in children as young as seven can have a serious effect on their future health."[43] Reportedly, 'Inactivity among children has now been linked to sedentary living among adults.'[44] Cycling effectively pays people to exercise by saving them time and money on a regular basis. It is fun and allows children to have their first independent form of transport, a pride of place for a child's development. Helmet promotion and laws focuses on danger, risks, coercion, police warnings, penalties, fines as opposed to enjoyment, fun and fitness that cycling brings. Helmet promotion is associated with reduced cycling[45] and also may divert full attention away from research and all the other means to improve health and safety.

Outcome of health and safety assessments

The WHO has developed an assessment method, "Quantifying the positive health effects of cycling and walking" and this can be used to evaluate changes in the level of cycling activity.[46] Child and youth health issues are very important so that they grow up into healthy adults. Recently the CTC (UK's national cycling organisation) has provided a detailed assessment of the effects a helmet law for all ages could have on the UK.[47] The CTC stated "we estimate that a law making helmets compulsory for cyclists may result in an overall *increase* in **253 premature deaths** (265 more from reduced cycling, 12 fewer from the reduced pool of cyclists receiving fatal head injuries)."

For the USA, introducing helmet laws for the under 16/18 year olds a similar calculation cannot be made directly because the method and research basis of calculating the premature deaths is considered only suitable for adult populations.[48] Where children have a high level of cycling activity they often continue to cycle as adults, e.g. in the Netherlands 60% of 11-15 years cycle, reducing to 46% for 16-20 age group and reducing again to 20+% for adults. In general the higher the proportion of child cyclists the higher the adult cycling rates. Introducing helmet laws for young cyclists is likely to lead to reductions in adult cyclists over time. For the USA there is an estimated 85.3 million cyclists and 37.1%

are under 16 years of age. Children 15 years and younger accounted for 55% of total hours cycled in 1998 (ref 4 Rodgers). Table 5 below shows cyclist killed and injured data for 1998.[49]

Table 5

	0-15 age	16+ age
Killed	230	531
Injured FARS	24000	29000
Injured hosp data	381600	215683

The main difference is adult may be commuters using busy roads whereas younger riders may use the pavement or cycle in areas away from traffic. A proportion of adults had also been drinking. Per hour of travel, younger cyclists probably gain more health benefits from cycling compared to the 16+age group, as their fatality risk is lower.

A precise estimate for the outcome from helmet legislation may not be possible as the health benefits for children cycling may exceed adults. Legislation for the under 16/18 age group leading to fewer children cycling may lead to fewer adults cycling in later years. Estimating for cycling reducing by 5% -10% is possibly a guide value for total effects.

From the estimate of 85.3 million cyclists and a mean riding time of 204 hours per year (ref 4 Rodgers) and assuming a 10km/hr average speed, on average 5km per cyclist per day would be cycled. Using the WHO assessment tool[50] and the 5% -10% values, calculates to 1496 – 2992 premature deaths by reduced cycling per year in the long term. The assessment tool is based on European data and adjusting for the USA, results in 1060 – 2120 premature deaths per year. Allowing for fewer cyclists, the approximate result would be between 1020 - 2040 premature deaths due to legislation. Deaths due to fewer people cycling may in part be transferred to pedestrian deaths, motorcyclists or other road users. Adults are not subject to the helmet laws and they may increase their cycling with concerns for health/fitness and in general road safety is improving. USA fatality rate per 100,000 people was 17.9 in 1990, 15.2 in 2000 and 12.2 in 2008, a 32% reduction from 1990. The UK value in 2007 was 5.0 therefore it is quite likely that the USA will continue to lower the fatality rate and more people may cycle as a result of safer conditions. Without helmet legislation even more people could be cycling than otherwise would occur. To summarise, a precise estimate is not possible but it is likely that helmet laws will result in between 1020 - 2040 premature deaths per year in the long term, at a cost of approximately $16 - $32 billion annually.

Relative risk and benefits of cycling

The basic fatality risk for a cyclist is roughly, number of cyclists, 85 million, divided by number of deaths per year, 700, about 1 in 120,000. The basic risk of adults becoming obese[51] or of dying from heart and circulatory disease is about 1 in 3.[52] Rodgers (ref 7, page 6/196) reported the risk for cyclists, stating, (Less than 3 percent of injury victims were admitted for hospitalization. This is about the same rate of hospitalization (about 4 percent) for all product-related injuries reported through NEISS in 1991). Cyclist hospital admissions appear to be about 18000 to 23000 per year from reports relating to the early 1990's. The basic risk of admission (for all injuries) is about once in 3700 years of cycling (85million /23000= 3695). Mills[53] from the UK reported that 66% of cyclist's admissions were detained for just one night and most of the casualties with cranium injuries were admitted for overnight observation. In Australia, a similar calculation found a serious head injury occurred once in 2500 years of cycling.[54]

The benefits of cycling have been detailed in the 'Health assessment' and using the WHO Health Economic Assessment Tool as a guide based on an estimated 85.3 million cyclists (ref 4 Rodgers) and 5km travel basis. The net gain from all cycling in the USA is about 21130 lives saved per year. The risk to benefit comparison for cycling is; 700 lost lives to

21130 saved, outcome 20430 saved. With helmet laws (assuming 10% reduced cycling activity) the figures are 630 lost lives to 19020 lives saved, outcome 18390 lives saved.

Without helmet laws 20430 lives saved, with helmet laws 18390 lives saved

Social and legal issues

Apart from imposing a legal requirement to use a product where the evidence is still in doubt about the safety merits, the public is also subject to possible legal issues. If a cyclist not wearing a helmet is injured due a motorist being at fault, the cyclist may be offered less compensation compared to a pedestrian or indeed a motor vehicle occupant who sustain head injuries. Discrimination in receiving fair compensation is one other issue that arises with cycle helmet laws. Without legislation, helmet manufacturers and retailers promote helmets. The 2004 European Council of Ministers (ECMT) report[55] states:
"Though helmets are widely accepted as reducing the severity of head injuries, the issue of mandatory requirements for helmet use has been controversial for a long time. PROMiSING , a research project commissioned by the European Union and coordinated by the SWOV Institute for Road Safety Research (2001), suggests that from the point of view of restrictiveness, even the official promotion of helmets may have negative consequences for bicycle use, and that to prevent helmets having a negative effect on the use of bicycles, the best approach is to leave the promotion of helmet wear to manufacturers and shopkeepers. The report entitled 'Head Injuries and Helmet Law for Cyclists' by Dorothy L. Robinson, Bicycle Research report No. 81 (March 1997) shows that the main effect of the introduction of the general helmet law for cyclists in Australia was a drop in bicycle use." Bicycle helmets need to be reliable and also they should not lead to discouraging cycling, evidence shows helmets fail on both issues.

In the USA, enforcement of helmet laws can result in a fine. Care is needed because in time enforcement may become a higher priority and have larger fines. In Victoria, Australia, with an all age helmet law and enforcement as a priority. Cycling reduced by 36% and in the first 12 months they issued more than 19,000 fines, from a population size of about 4.5 million. One in 240 people were fined. For the 60+ million under 16 years of age in the USA, approximately 250,000 could be fined each year if enforcement increased. Safety relates to 'Safety in Numbers', the more people cycling the safer it becomes.[56] When more people cycle, drivers expect to encounter cyclists and drive more carefully. This effect may also benefit pedestrians who incur 6 times more fatalities than cyclists. Unpaid fines have resulted in people being locked up.[57] Children being stopped and questioned by the police may result in undesirable consequences. In part of Georgia the police impounded 167 bicycles, averaging of 1 per day. In Dallas the police have been enforcing the use of helmets on all riders.[58] One adult cyclist has challenged the ruling saying; "It's wrong, it discourages people from biking," see the court ruling THE CITY OF DALLAS, Appellant, v. PAUL C. WOODFIELD, Appellee[59]. In Austin, Texas, between 1997-99, 92% of kid tickets for not wearing helmets went to minority kids, typically black & Hispanic kids.[60] As in Dallas and in parts of Canada, the focus for helmet promotion and legislation can soon change to adults, "This is the third attempt in the past four years that Milloy and his friends have tried to legislate helmets on to adult Ontario cyclists."[61]

Why cycle

Most young cyclists ride for recreational purposes, fun, enjoyment and pleasure. Others may ride as a mean of transport. Prior to helmet laws in 1987, O'Rourke reported, "Generally, the younger age group (those aged five to seven years) were in favour of wearing helmets, whereas older children were opposed to the wearing of helmets."[62] Surveys from Melbourne showed 30 more teenagers wearing helmets but 623 fewer cycling after their helmet law.[63] One reason people cycle is they enjoy riding. It is a critical issue to understand, exercise alone can be done by many means but cycling can be more. Virtually cost free, independent travel, an acquired skill, alone or with others, time saving, exercise and individualistic in nature. Part of the enjoyment stems from the freedom it

gives to travel unassisted almost anywhere and unencumbered. It can for some people be the closest they come to feeling as free as a bird. It can also be seen as dangerous, pedalling along on a busy road with heavy traffic going too fast, where the risk factor is often higher for all road users. However, the main reason people cycle is to do with the former, of enjoyment, see cyclists in Rotterdam.[64]

Helmet requirements can detract from the enjoyment of cycling, a barrier to viewing cycling in its best form. Helmet laws remove freedom of choice and thereby slices into that area of personal respect in making a choice. For young people, enjoying physical activity is a key element in taking part and an important part of growing up. Helmet laws try to force people into wearing them with threats of fines or police involvement. This infringes on the main reason for cycling and is part of the discouraging process.

Are helmet laws worthwhile, is helmet promotion worthwhile?
A recent USA report 'Pedestrian and Bicyclist Safety and Mobility in Europe' provided a summary of the European approach to helmets stating: "Bicycle helmet use is encouraged, but not required by law. The scan team found higher levels of bicycle helmet use than expected in the countries visited. Helmets were uniformly encouraged for children and adults. Most countries emphasized physical activity first and helmets second. Their rationale was that required helmet use discourages bicycling (physical activity), which could have a greater public health detriment than head injuries due to crashes. Bicycle helmet use was recognized not as a crash-prevention measure, but as the most effective countermeasure for preventing head injury from a bicycle crash."[65]

There is a basic health problem with helmet legislation that makes it not worthwhile. The fatality risk factor for cyclists is 1 in 120,000 and if helmets could prevent 10% of deaths (they do not because of other serious injuries, chest for example, and they incur more impacts due to the extra size of a helmet) then 1 in 1,200,000 may be saved. In practice about 33% or more may wear helmets without a law, meaning possibly 67% do not wear them. In Australia they had a 36% reduction in cycling due to their helmet law, meaning roughly half of the non-wearers stopped cycling. So the hopeful gain from a helmet law would be one life saved from 1.2 million cyclists, however from 1.2 million non-wearers, 600,000 may stop cycling and increase the risks of more heart disease, stroke, diabetes etc. The WHO formula, which can be used to calculate lives saved be cycling, shows that from 600,000 people cycling, approximately 120 lives can be saved. The end result, a helmet law, can result in 120 times more harm than the intended good. Of course with an increase in the accident rate (14%, ref 23, page 28), extra harm results, plus people are fined and children stopped by the police.

Clearly helmet laws are not worthwhile, however is helmet promotion worthwhile? For the USA a guide assessment may be helpful, with approximately 100 cyclist deaths for the under 16-age group. Making an optimistic assumption that 10% of lives could be saved by helmet use, 10 lives in total. The WHO health formula suggests approximately one life saved per 5000 cycling, therefore, if 50,000 were discouraged by helmet promotion, no net benefit would occur. For the under 16 age group more than 30 million have bicycles and if 2% were discouraged it would involve 600,000, effectively a loss of 120 lives. UK data suggest helmet promotion may have discouraged cycling by 2.8%, or more (ref 45). The proportion of children cycling to school from 1987 to 1991 in Western Australia reduced 20.9% to 11.9% with helmet promotion,[66] effectively reduced by 40%. In St Louis parents have been warned they could be fined for their kids not wearing helmets[67] (If your child rides a bike and doesn't wear a helmet, you could get a fine. The law could make Illinois parents pay $30 for each child not wearing a helmet). Will parents be so inclined to buy children bicycles if they start to receive fines, is the long-term question that may arise. Dr Hillman considered the issue of promotion in his 1993 report[68] and concluded cyclists may gain an exaggerated expectation of helmets being effective, therefore he did not recommend promotion. There are also safety issues to consider and on balance helmet

promotion is not warranted. The end result, helmet promotion, can result in 12 times more harm than the intended good.

Helmet promotion via sporting events is one other issue to arise. Organisers of events have their views and possibly insurance plus health and safety issues. In cases where a cyclist does not believe they should have to wear a helmet, the cyclist's view should be respected. This ensures human rights in following their own beliefs is upheld, no one is discouraged from taking part, reduced head impacts and fewer accidents may result. Event organisers or cycling organisations do not have the right to override basic human rights and impose a helmet requirement or prescribe it as a condition for taking part, thereby discriminating against cyclists who may not believe in the safety merits or have other reasons for not wearing a helmet. The Universal Declaration of Human Rights 1948, Article 2[69] tries to ensure rights and freedoms exist without distinction of any kind. The Tour de France cycle race has incurred 2 deaths, possibly helmet related, in its 100 plus years of racing history.[70] In 1935, Francisco Cepeda plunged down a ravine and in 1995 a Fabio Casartelli crashed at 55 mph. It is somewhat doubtful if wearing a helmet would have made any difference in the outcome for both riders. In comparison, the Isle of Man TT motorcycle races, between 1907 and 2009, there have been 227 deaths during official practices or races and probably most of these were wearing helmets. Organisers can design their events to be low risk if they have safety concerns and they should not lead cyclists into taking excessively dangerous activities incurring serious injuries and calling it a sporting event.

Conclusions

Cycling poses a lower risk to other road users than motor vehicles and it is an environmentally friendly means of transport with the health benefits outweighing the risks. Great care should be exercised to ensure cycling is not discouraged. This means, not imposing helmet laws that have been shown to discourage cycling. The USA fatality data and survey information shows that state helmet laws have not provided substantial benefits to health and safety. The fatality data comparisons in part 1, 2 and 3 suggest helmets do not provide a significant value in saving lives. States without helmet laws have probably gained more by allowing their young people to cycle without making cycling more inconvenient and less enjoyable for some. Survey data, 1998 to 2007, shows cycling reduced by 29.9% for 7-11 year age group. As a guide, the outcome of the health and safety assessment, suggests that helmet promotion and legislation may have resulted in 1020 – 2040 premature deaths per year in the long term. Cycling assists people to avoid the problems of obesity, diabetes and heart disease and it does not make sense to introduce helmet laws that discourages a proportion of people from cycling. The results from the USA are similar to Australia were Curnow[71] concluded that "Compulsion to wear a bicycle helmet is detrimental to public health". For young cyclists enjoyment of physical activity is very important and helmet requirement has a discouraging effect. Balancing all the issues, the conclusion reached is that helmet laws for bicyclists, including children and youth, are a mistake. The estimated guide value is that helmet laws can result in 120 times more harm than the intended good and helmet promotion 12 times more harm than good.

The UK's National Children's Bureau (NCB) provided a detailed review in 2005[72] stating "the case for helmets is far from sound", "the benefits of helmets need further investigation before even a policy supporting promotion can be unequivocally supported" and "the case has not yet been convincingly made for compulsory use or promotion of cycle helmets." The benefits of helmets are overstated and the costs of chronic health conditions, including obesity, among children and youth are massive. The ECF (European Cycling Federation) stated "the evidence from Australia and New Zealand suggests that the wearing of helmets might even make cycling more dangerous,"[73] indicating safety was actually reduced. It is not certain that helmets actually improve safety.

States with helmet legislation should repeal their laws and the USA should reconsider its approach to helmet promotion. Road safety improvements to reduce road danger to all road users, is probably the better approach, e.g. lowering the drink drive limit from 0.08 to 0.05 BAC could save many lives each year, including cyclists. Alternatives to improve safety are available: cycle training, separating heavy good vehicles from cyclists, advanced stop lines for cyclists and refinements to speed control. Improvements to driver attitudes to cyclists, taking more care is very important. Developing a cycling culture to minimise risks, avoid accidents and promote cycling for health, rather than a culture of helmet promotion for protection. A real effort to improve cycle safety for children should be made by applying science and without the use of helmets. The WHO should provide funding to the European Cycling Federation for research into reducing cycle accidents without the use of helmets. Additional information on cycle helmets can be found at, www.cyclehelmets.org, www.cycle-helmets.com and www.vehicularcyclist.com.[74]

Appendix 1
Comparing cyclists to motorcyclists and others

In 1998 motorcyclists travelled approximately 10283 million miles[75] (at 30mph average speed would be 343 million hours) and had 2294 fatalities. On average, one per 0.1494 million hours. Survey data reported 17000 million hours of cycling in 1998 (ref 4 Rodgers) with 761 fatalities. On average, one per 22.3 million hours. The data suggests cyclists are about 150 times safer per hour of travel compared to motorcyclists. Australian data from 1988 on travel and fatalities indicates cyclists (generally not wearing helmets) were about 18 times safer per hour of travel, motorcyclists had 7.66 fatalities per million hours, (ref 20 Robinson) similar to the USA estimate of one per 0.1494 million hr or 6.7 per million hours. Australian data for cyclists indicated one death per 2.4 million hours. USA survey data may have included children's playing time on bikes, in parks etc. The overall USA fatality rate in 1998 was1.6,[76] (Fatality Rate per 100 Million Vehicle Miles Traveled). If estimated for an average speed of 25 mph, this would equate 1 per 2.5 million hours. Cyclists may be at a similar risk of being killed per hour compared to car occupants. In 2000, the leading cause of fatal unintentional injury among children (0-14 years) was motor vehicle occupant injury 28%, drowning 16%, airway obstruction injury 14%, pedestrians 12% and cycling 3%.[77]

Appendix 2
Helmet warnings

To safeguard the public, a number of warnings should be included with helmet sales.

1 Helmets are designed for low speed impacts and they may not provide sufficient protection in many accident situations.

2 Children should not wear helmets on playgrounds or when climbing trees. The helmet can snag and the strap can asphyxiate them. Several deaths have been recorded.

3 Some research evidence suggests that helmets may increase the accident rate and extra care may be advised.

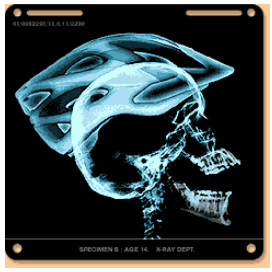
4 Helmets are not tested for rotational acceleration effects, which are associated with serious brain injury. They may double the impact rate compared with a bare head and also increase the torque for rotation by approximately 30% or more.

5 The consumer magazine *Which?*[78] independently tested 24 helmets and reported that only 9 passed all tests and therefore even new helmets may not be reliable.

6 The health benefits of cycling generally exceed the injury risk and children or adults should not be forced or coerced into wearing them if it discourages them from cycling.

Appendix 3
List of states with helmet laws
State Ages Covered Effective Date
Alabama under 16 9/19/1995
California under 5 1987
California under 18 10/8/1993
Connecticut under 15 10/1/1993
Connecticut under 16 5/14/1997
Delaware under 16 4/1/1996
District of Columbia under 16 5/23/2000
Florida under 16 1/1/1997
Georgia under 16 7/1/1993
Hawaii under 16 1/1/2001
Louisiana under 12 3/1/2002
Maine under 16 9/18/1999
Maryland under 16 10/1/1995
Massachusetts under 5 1990
Massachusetts under 13 3/8/1994
Massachusetts under 17 11/25/2004
New Hampshire under 16 1/1/2006
New Jersey under 14 7/1/1992
New Jersey under 17 3/1/2006
New Mexico 2006
New York under 5 1989
New York under 14 6/1/1994
North Carolina under 16 10/1/2001
Oregon under 16 7/1/1994
Pennsylvania under 5 1991
Pennsylvania under 12 2/1/1994
Rhode Island under 9 7/1/1996
Rhode Island under 16 1998
Tennessee under 12 1/1/1994
Tennessee under 16 2000
West Virginia under 15 7/1/1996

Appendix 4
Comparing impacts for helmeted and non-helmeted
DfT - UK, X-ray images, ratio head to helmet width 1.46 – helmet width is 46% larger than the bare head. The X ray images indicate a helmet thickness could be from about 25 to 60 mm.



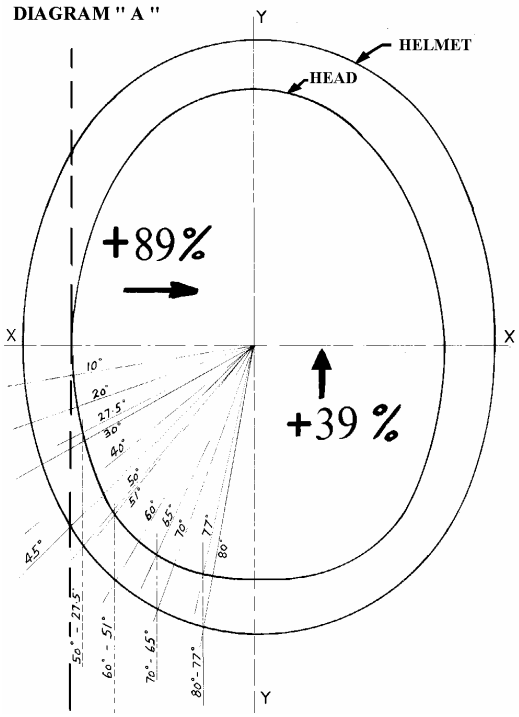


Diagram A has a head to helmet width ratio of 1.27 (ref 21) refer
http://www.ta.org.br/site/Banco/7manuais/colin_clarke_cycle_helmet.pdf
http://www.nationaler-radverkehrsplan.de/eu-bund-laender/eu/velocity/schedule.phtml

Comparing forces for a head to helmet width ratio of 1.36 (Clarke 2007 method)
Comparison of forces to the head/helmet for helmeted and non-helmeted in the X and Y directions, based on a simple frontal approach motion of possible impacts and a ratio of head to helmet width of 1.36 (between size shown in Diagram A, 1.27 and DfT X ray images, 1.46)

Helmeted:-			……. $(\text{Sin Q})^2$ ……	(Sin Q x Cos Q)
Angle……	Sin	Cos	Y frontal…..	X sidewards
5…..	.0871	.9962	.0076	.0866
10……	.1736	.9848	.0301….	.1709
15……	.2588	.9659	.0669	.2500
20……..	.3420	.9396	.1169 ….	.3213
25…….	.4226	.9063	.1786	.3830
30 ……	.5000	.8660	.2500 ….	.4300
35……	.5735	.8191	.3290	.4698
40……	.6427	.7660	.4130….	.4923
45…….	.7071	.7071	.5000	.5000
50……	.7660	.6427	.5867….	.4923
55…….	.8191	.5735	.6710	.4698
60……	.8660	.5000	.7500….	.4330
65……	.9063	.4226	.8214	.3830
70……	.9396	.3432	.8828 ….	.3213
75…….	.9659	.2588	.9330	.2500
80……	.9848	.1736	.9698….	.1709
85……	.9962	.0871	.9924	.0868
90…….	1.0000	.0000	1.0000…	.0000
…….		Totals	**9.4993**	**5.7109**

Total 15.21 from 18 impacts,

Non-helmeted:-
Corresponding impacts for above, angles below 50 degrees would be misses or near misses.

			……. $(\text{Sin Q})^2$ …….	(Sin Q x Cos Q)
Angle……	Sin	Cos	Y frontal…..	X sidewards
50 – 0 …	……0……	1.0	0	0.0
55 – 33	.5446	.8386	.2966	.4567
60 – 46	.7193	.6946	.5174	.4997
65 – 56	.8290	.5592	.6873	.4635
70 – 63	.8910	.4540	.7939	.4045
75 – 71	.9455	.3255	.8940	.3078
80 – 76.5	.9723	.2334	.9454	.2269
85 – 83.5	.9935	.1132	.9872	.1125
90 – 90	1.0000	.0000	1.0000	.0000
	Totals		**6.1219**	**2.4716**

Total 8.59 from 8 impacts,

A comparison of the impact forces, helmeted total 15.21 and 8.59 for non-helmeted. Total helmeted forces were 77% HIGHER based on a head to helmet width of 1.36

Comparing impacts
Based on the above comparison, total combined forces for helmeted impacts were 77% higher than for non-helmeted forces, 15.21 to 8.59. Total impacts for helmeted were 18 compared to 8 for non-helmeted, up 125%. For a bare head the impact may result in higher acceleration for shorter duration compared to helmeted having lower acceleration and longer duration, due to padding. Higher acceleration and longer duration both increase the risk of head injury.

Rotational acceleration levels
Testing for rotational accelerations involving both vertical and lateral movement relates more directly to a cyclist falling from a moving bicycle. A slight difference in the size of helmet has resulted in major difference in the level of rotational acceleration, a major factor in brain injury. StClair and Chinn 2006 report, Table 4.9, provides test results for helmet sizes E and J, 54cm and 57cm respectively. Average rotational acceleration for size E were 5333 rad./sec ^{2} compared to J size of 13505 rad./sec.^{2} A small difference of just 3 cm resulted in the rotational levels increasing by 250% and the difference between a helmeted and non-helmeted head is approximately 18 cm.

Helmets in general are not designed to limit rotational acceleration and Lane[79] reported "it has been recognised since the work of Holbourn (1943) that rotational acceleration of the head plays a major part in brain injury". Lane details the threshold limits suggested by Lowenhielm of 4500 rad/sec/sec for AIS 5. AIS 5, being critical injury level. StClair and Chinn page 3, suggest a maximum rotational level tolerance for human adult head 10000 rad./sec ^{2}, children's tolerance may be lower. For the J size results the average resultant force was 4228N.

A slight increase in helmet size, E to J, can lead to a major increase in risk of brain injury. A bare head provides the minimal risk of head contact in the event of a fall or accident. The effects of crushing the EPS form may help to reduce rotation but many helmets on inspection do not show signs of being crushed and most helmets do show signs of impacts to the side, areas where a near miss may occur for a bare head. Research over the past 50 years indicates angular acceleration is more damaging than linear acceleration. Based on the increase in impacts and tests from rotational experiments it would not be safe to assume the effect of padding provided by a helmet, will outweigh the effect of the geometry and the increased size of helmet compared to a bare head.

Neck injuries
Actual neck injury data indicates helmet use may not provide any benefit. Attewell[80] states "Three studies provided neck injury results that were unfavourable to helmets with a summary estimate of 1.36(1.00, 1.86), but this result may not be applicable to the lighter helmets currently in use". From this it is not clear if any helmet could increase the risk of a neck injury or if the risk is proportional to the helmet weight, or a combination of factors.

Appendix 5
Recommendation
A number of measures could be introduced or researched that may improve health and safety:

1) Repeal state bicycle helmet laws, saving in premature deaths.

2) Bicycle helmets sold with the 6 warnings, suggested in Appendix 3.

3) Cycle training be improved for young children, age related - type of bicycle or tricycle to use, fitting to size, pre cycling - balance on scooter stage, staged development to reduce risk of falling.

4) Advanced research into bicycle riding stability and control to lower the risk of falling. Suggest that the WHO provide funding to enhance cycle safety without promoting helmet.

5) Advanced stop lines for cyclists at traffic lights.

6) Prohibiting parking within 10m of junctions on roads having a 30 mph or higher speed limit and 8m of junctions on roads having a 25 mph or lower speed limit.

7) Lowering the drink drive limit from 0.08 to 0.05 BAC. In 2008, 11,773 people were killed in alcohol-impaired-driving crashes.

8) Reducing the level of danger on major roads, e.g. provide wide inside lanes, special left turn arrangements if risk is high, i.e. hook turn as used in Melbourne on tram crossing junctions.

9) Identify high-risk type vehicles to cyclists, e.g. in London HGV type vehicles and buses. Make the public aware of findings, especially cyclists and take suitable measures to reduce risks. School poster showing high-risk type vehicles.

10) Requiring Hybrid Electric Passenger Vehicles (HEV) to emit sound levels similar to internal combustion engine (ICE) vehicles. (would help pedestrians, cyclists and people with impaired sight).

11) TV adverts saying check behind before opening car doors.

12) Assessment if yellow coloured center lines used in the USA should be replaced with white lines for higher contrast and better for older drivers to see.

13) For general cycling, in all legal and accident compensation claims, the non-use of helmets should not be used as a basis for reducing compensation.

Appendix 6
List of cost estimates

1. Non-fatal bicycle injuries in children and youth age 0 to 19, was $3.6 billion.[81]

2. Total cost of obesity in the United States was estimated to be $117 billion.[82]

3. Cost of diabetes in 2007 was estimated at $174 billion

4. According to the American Heart Association,[83] all cardiovascular diseases together are projected to cost $475.3 billion in 2009.

5. Cost of reduced cycling1020 - 2040 premature deaths per year in the long term, at a cost of approximately $16 - $32 billion annually.

Appendix 7
Cycle choice for children
USA data shows head and face injuries were 50% of total injuries for children younger than 10 years old, compared to 19% for all cyclists over 10 years old (ref 7 Rodgers, p 60/169). Australian, VISS information[84] Fig 1 below shows a similar outcome for hospital treatments, 10% head and 24% face.

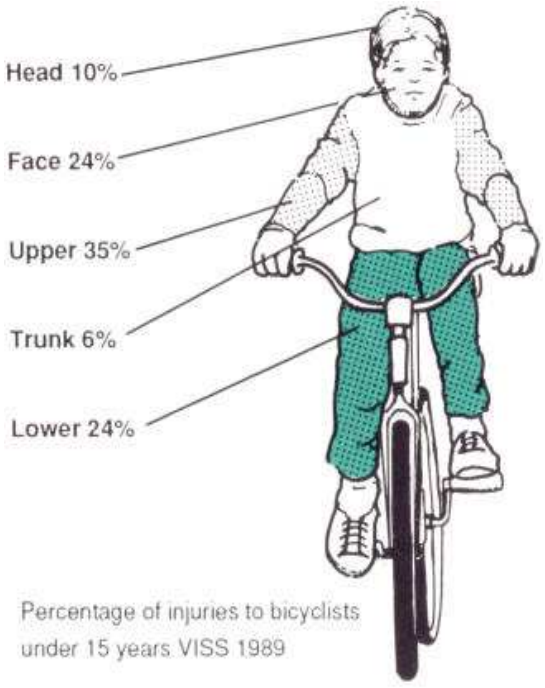


Fig 1

Face injuries are roughly double head injuries. Most head and face injuries are cuts and abrasions (69%, ref 7, Rodgers, Table 3, p69/169). For the younger cyclist, loss of control is probably the most common cause of accident. A step progression from about age 2 onwards in the choice of cycle/scooter could help reduce the risk to children, as listed: As soon as the child starts to use wheeled equipment on the pavement, instructions about giving way, looking both ways and crossing where they can be seen should be given.

0-2 years: this age is too young for riding bikes or scooters, toddlers should be reminded not to touch wheels or chains.

2-3 years: Small tricycle, no chain, pedals via front wheel drive or no pedals. Suitable for level ground away from roads. Low tyre pressure (L.T.P.) will help to keep speed low.

3-4years: Larger tricycle, similar to above, but with basket on rear for carrying toys.

4-5 years: to become used to balancing on two wheels, suggest a good quality scooter, larger wheels, possibly with brakes should be used for a period, L.T.P. Schools could reinforce the safety messages of "looking both ways and cross where you can be seen".

5-6 years: Two wheel unisex design bicycle without cross bar. Enclosed chain drive, single speed, two brakes, L.T.P.,

7 –8 years: single speed bikes may reduce the risks due to being less distracting for rider but multi geared bikes may be preferred. Safety appears to be mainly related to attitudes and avoiding high risk type cycling. Providing a display chart of suitable equipment for younger cyclists may help, height – wheel size and frame size, would allow children to check their own bike for size as the grow. The front cover of '*7 REASONS TO OPPOSE A CHILD HELMET LAW*' provides two example of the bicycle size to match the child.[85]

8 years plus: cycle training, measurable balance index per child, full assessment leading to a lower risk of loosing control when cycling

Appendix 8
Author details

Cycling background includes 50 years of cycling experience, covering approximately 300,000 miles and visiting more than 20 countries, plus having working experience in cycle training and as a road safety instructor. Qualified as a British Cycling Federation Coach in 1970, having had cycle racing experience from 10 miles to 200+ miles. Cont.

Researched and written the following:

1 Safer Cycling 1st Edition 1995, 80 page technical booklet detailing cycling and ` safety issues plus information regarding helmets and legislation.

2 Bicycle helmets and accident involvement; Cycling World, UK, June 2003, a technical article relating helmets and the accident involvement rate.

3 Safety in numbers for walkers and cyclists; Health Promotional Journal of Australia, Vol 16, No 2, 2005, a letter detailing many of the concerns that exist relating to cycle helmet laws.

4 The Case against bicycle helmets and legislation, Canadian Multidisciplinary Road Safety Conference, Winnipeg, Manitoba, Canada 2006. A paper presented at the main road safety annual conference in Canada explaining the basic case against helmet use and legislation.

5 World Transport Policy & Practice Volume 12, No. 2, 2006 The case against bicycle helmets and legislation http://www.eco-logica.co.uk/pdf/WTPP12.3.pdf

6 The Case against bicycle helmets and legislation, VeloCity cycling conference, Munich 2007. A detailed report presented at the world's leading cycling conference providing details showing how helmet use and legislation has reduced both health and safety in general terms. http://www.nationaler-radverkehrsplan.de/eu-bund-laender/eu/velocity/schedule.phtml or http://www.ta.org.br/site/Banco/7manuais/colin_clarke_cycle_helmet.pdf

7 Assessment of Australia's Bicycle Helmet Laws, refer 'Mandatory' can have unanticipated consequences – Civil Liberties Australia web site, 25 Nov. 2008. Providing details of the effects of the legal requirement to wear cycle helmets. http://www.cla.asn.au/Article/081125BikesHelmetPolicy.pdf

8 Evaluating bicycle helmet use and legislation in Canada, 2009. http://www.cycle-helmets.com/canada-hel ... ssment.doc This paper evaluates helmet law effects on children for provinces with helmet legislation and compares to provinces without legislation for the period 1994 to 1998. It shows a relative net benefit for those without legislation.

Acknowledgements
Thanks are due to the National Center for Statistics & Analysis, USA for data provided on fatalities. Thanks also to the Bicycle Helmet Research Foundation for detailed information and to Mr Don Journet for his assistance.

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