

BMJ Open

Impact of daylight saving time on road traffic collision risk: a systematic review

Journal:	<i>BMJ Open</i>
Manuscript ID	bmjopen-2016-014319
Article Type:	Research
Date Submitted by the Author:	16-Sep-2016
Complete List of Authors:	Carey, Rachel; University College London, Department of Clinical, Educational & Health Psychology Sarma, Kiran; National University of Ireland, Galway,
Primary Subject Heading:	Public health
Secondary Subject Heading:	Evidence based practice, Health policy
Keywords:	Road safety, Daylight saving time, Collision risk, Systematic review

SCHOLARONE™
Manuscripts

Peer Review Only

Running Head: IMPACT OF DAYLIGHT SAVING TIME

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

**Impact of daylight saving time on road traffic collision risk: a
systematic review**

Rachel N. Carey¹ (PhD) & Kiran M. Sarma^{*2} (PhD)

¹Department of Clinical, Educational and Health Psychology, University College London, 1-
19 Torrington Place, London WC1E 7HB, United Kingdom.

² School of Psychology, National University of Ireland, Galway, University Road, Galway,
Ireland.

Email: kiran.sarma@ucl.ac.uk; Telephone: +353 91 495715

*Corresponding Author

Word Count: 3021

Running Head: IMPACT OF DAYLIGHT SAVING TIME

Abstract

Background: Bills have been put forward in the United Kingdom and Republic of Ireland proposing a move to Central European Time (CET). Proponents argue that such a change will have benefits for road safety, with daylight being shifted from the morning, when collision risk is lower, to the evening, when risk is higher. Studies examining the impact of Daylight Saving Time (DST) on road traffic collision risk can help inform the debate on the potential road safety benefits of a move to CET. The objective of this systematic review was to examine the impact of DST on collision risk.

Methods: Major electronic databases were searched, with no restrictions as to date of publication. Access to unpublished reports was requested through an international expert group. Studies were included which provided a quantitative analysis of the effect of DST on road safety-related outcomes. The primary outcomes were road traffic collisions, injuries and fatalities.

Findings: Twenty-three studies met the inclusion criteria. Sixteen examined the short-term impact of transitions around DST and 11 examined long-term effects. Findings from the short-term studies were inconsistent. The long-term findings suggested a positive effect of DST. However, this reduction cannot be attributed solely to DST, as a range of road collision risk factors vary over time.

Interpretation: The evidence from this review cannot support or refute the assertion that a permanent shift in light from morning to evening will have a road safety benefit.

Keywords: Systematic review, road safety, daylight saving time, collision risk.

Running Head: IMPACT OF DAYLIGHT SAVING TIME

Article Summary

Strengths and limitations of this study

- This review draws together evidence of the impact of shifting time-zones on road traffic collision risk and is, to our knowledge, the first systematic review that can inform current debates on time-zone changes.
- A key strength of this review is the examination of collision risk across different types of road users and time of day, reflecting the complex array of factors that are implicated in the relationship between light and collision risk.
- A diverse range of analytic and statistical approaches were adopted in the included studies and we were therefore unable to combine the findings through meta-analysis.
- The long-term findings reported in this review are arguably less relevant than the short-term findings, since a range of risk factors for road traffic collisions vary in the long-term (e.g. traffic flow and weather conditions).

Running Head: IMPACT OF DAYLIGHT SAVING TIME

Impact of daylight saving time on road traffic collision risk: A systematic review

In recent years, Bills such as the *Brighter Evenings Bill*, have been put before parliaments in the United Kingdom (UK) and Republic of Ireland (RoI) that, if enacted, would result in these jurisdictions changing time-zone from Greenwich Mean Time (GMT) to Central European Time (CET). These jurisdictions would not be the first to adjust time-zones. China historically changed time zones within its borders [1] and, more recently, Russia [2] and North Korea [3], among others, have experimented with time-zone changes. Currently, there are a number of countries, including Spain [4], contemplating similar shifts.

For the UK and RoI, the change would impact on approximately 70 million people. In practice, it would mean that the sun would rise and set one hour later than at present, leading to darker mornings and brighter evenings. Proponents of the Bills argue that such a change would have economic benefits, arising from the alignment of the working day across EU economic partners, and societal benefits, including a reduction in road traffic collisions, injuries and fatalities [5].

The assertion that a move to CET would have a positive impact on road safety is rooted in the relationship between light and collision risk. It has been argued that road traffic collision risk is at its highest in the late afternoon and evening hours (c. 15.00 to 19.00) and that, on some level, this arises due to the interaction between deteriorating lighting conditions and other risk factors, including fatigue [6 7]. To the extent that evening collision risk derives from poor light, shifting an hour of daylight from the morning, when collision risk is lower, to the evening, when collision risk is higher, should lead to an overall net reduction in road traffic collisions [5 8 9]. This should be particularly marked during the autumn and winter months when the evenings are darker and weather conditions less favourable for road users [5].

Running Head: IMPACT OF DAYLIGHT SAVING TIME

1
2
3 This argument has found some support in the empirical literature. Broughton and
4 Stone, for example, have produced an authoritative study on the likely effects on road
5 collisions of adopting Single/Double Summer Time (SDST, i.e. CET) year-round. Using
6 mathematical modelling procedures to estimate casualty incidence, they estimated that a move
7 to CET would lead to an overall reduction in fatalities of between 2.6 and 3.4%, and a
8 reduction in serious injuries of 0.7% [7]. The UK's Royal Society for the Prevention of
9 Accidents (RoSPA) recently drew similar conclusions, arguing that any increase in a morning
10 collision peak will be 'more than off-set by the reduction in the higher evening peak' [5, p.1].

11
12
13
14
15
16
17
18
19
20
21 The overall trends relating to collisions across time of day appear, at first glance, to
22 support some of the core assumptions behind the CET argument. However, the extent to
23 which collision risk is actually impacted by shifting light and time is unclear, and difficult to
24 expose to scientific enquiry for a number of reasons. First, most of the UK studies on CET are
25 based on data derived from the 1968-1971 British Standard Time (BST) experiment, during
26 which the UK remained in Daylight Saving Time (DST) year-round. As noted by the
27 Transport Research Laboratory [7], 'conditions have changed since the end of the experiment
28 and the results cannot be applied directly to current conditions' (p. 3). Specifically, there have
29 been substantial changes in traffic levels, road infrastructure and road user behaviour in the
30 past five decades that mean the 1968-1971 experiment may be of limited relevance. Second,
31 evidence suggests that light is rarely a direct cause of collisions. Instead, light and darkness
32 tend to compound more direct causal factors. For example, driver performance deteriorates
33 under poor lighting conditions, due to diminished visual reaction times and impeded ability to
34 process core information like critical stopping distances. Collisions in this context are caused
35 by driver error - error that can occur under both ambient and dark conditions, but which are
36 compounded under the latter [10]. Similarly, light can interact with environmental factors, like
37 rain, frost and snow, to inflate crash risk.

Running Head: IMPACT OF DAYLIGHT SAVING TIME

1
2
3 The impact of a move to CET is not easily estimated, given the complex array of
4 factors implicated in collisions. One method for examining its potential impact is to look at
5 transitions into and out of Daylight Saving Time (DST). DST refers to the practice of
6 adjusting the clock time to create extra daylight during periods of waking activity [11]. In the
7 northern hemisphere, clocks are set forward by one hour in spring, providing an extra hour of
8 daylight in the evenings, and revert back to standard time (ST) in the autumn, leading to an
9 extra hour of daylight in the mornings. DST shifts provide a naturalistic experiment that can
10 yield estimates as to the association between light and collisions. Particularly in the short-term
11 (typically 1-2 weeks around the transitions), these estimates can be considered to account for
12 the influence of traffic and pedestrian-flow and which are believed not to relatively stable over
13 short periods of time. Longer term studies (typically 3 -13 weeks around the transition) may
14 also provide insights, provided other explanatory variables have been statistically controlled
15 for.

16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32 Several studies have empirically investigated the short-term and long-term impact of
33 DST on road safety. However, these studies have taken place in different jurisdictions, and
34 used a variety of statistical and methodological approaches. Given that a key argument
35 currently being put forward for a move to CET is the potential road safety benefit, there is a
36 need for these studies to be systematically synthesised. Such a synthesis would allow us to
37 extrapolate key lessons from the literature base, to address over-reliance on individual studies,
38 and to overcome any tendency to selectively attend to evidence that supports a particular
39 position relating to shifting time-zones. This paper summarises the findings of the first
40 systematic review of the literature relating to the impact of DST on road safety.

41
42
43
44
45
46
47
48
49
50
51 The review addressed the following research question:

- 52 1. What is the impact of DST on road traffic collisions, injuries and fatalities
- 53 a. On morning vs. evening risk?

Running Head: IMPACT OF DAYLIGHT SAVING TIME

- 1
2
3 b. On different types of road users (e.g. vehicle occupants vs. pedestrians,
4 cyclists, etc.)?
5
6
7
8
9

10 **METHODS**

11 **Search Strategy and Selection Criteria**

12
13
14 We conducted a systematic review of the literature pertaining to the impact of DST on
15 road safety outcomes. Studies were included which provided a quantitative analysis, using
16 primary data, of the effect of DST on road safety-related outcomes (i.e. road traffic collisions,
17 injuries and fatalities). Only studies published in English were included in the final review.
18
19 We excluded qualitative studies, opinion pieces, and newspaper/magazine articles, where no
20 primary data were analysed. Studies were also excluded if they artificially constructed a
21 change in lighting conditions (e.g. in a laboratory experiment), if potential effects of DST
22 were discussed but not controlled for in the analysis, if the analysis did not specifically focus
23 on the impact of DST, and/or if the analysis related to time-zone changes and not DST.
24
25 Studies involving all populations (i.e. all types of road users) were included.
26
27
28
29
30
31
32
33
34
35

36 Papers were identified by conducting computerised searches of the Cochrane, EBSCO,
37 Google Scholar, PsycInfo, PubMed, SafetyLit, Science Direct, Scopus and Web of Science
38 databases. We also searched ProQuest for 'grey' literature. Keywords informed by pilot
39 scoping exercises, included daylight saving, DST, time change, road safety, road traffic
40 collision, crash, accident, fatalities, and injuries (e.g. "daylight saving*" OR DST OR "time
41 change" AND "road safety" OR "road traffic" OR collision OR crash OR accident). A request
42 for papers was also sent to the International Traffic Safety Data and Analysis Group.
43
44 Representatives from more than 30 road safety agencies world-wide, as well academic
45 institutions and members of the automobile industry, are members of the group. Although this
46 review aimed to examine the impact of shifting time-zones on collision risk and health
47
48
49
50
51
52
53
54
55
56
57
58
59
60

Running Head: IMPACT OF DAYLIGHT SAVING TIME

1
2
3 outcomes, patients were not involved in setting the research agenda or in the conduct of the
4
5 review.
6
7

8 9 10 **Data Collection and Analysis**

11 One reviewer reviewed titles and abstracts of all returned papers to identify potentially
12 relevant studies, and a second reviewer checked 15% of these for agreement (Kappa = 0.8).
13 Discrepancies were resolved through discussions between the authors. On the basis of the
14 abstract, full texts were retrieved for all studies that (i) met the inclusion criteria or (ii) did not
15 provide enough information in the abstract to determine eligibility. One reviewer reviewed the
16 full-texts to determine eligibility for inclusion and this was checked, for 15% of studies, by a
17 second reviewer (Kappa = 1.00). Where multiple papers referred to the same analysis on the
18 same data-set, these were included in the review as one study only.
19
20
21
22
23
24
25
26
27
28

29 Data extraction was conducted by two reviewers using a standardised form. The
30 following data was extracted from studies: location, year(s) captured, timeframe captured,
31 where data was retrieved from, research question(s), variable(s) included in analysis,
32 outcome(s), findings, whether the analyses related to short- or long-term impact, type of
33 statistical analyses used, and whether or not the analyses were broken down by (i) road user,
34 (ii) time of day (i.e. morning vs. evening), and (iii) time of year (i.e. spring DST change Vs
35 autumn DST change). Data were synthesised using narrative synthesis [12]. An initial scoping
36 of the literature-base suggested that studies used a range of statistical approaches, and made
37 varying statistical assumptions, and as such we did not seek to combine the findings through
38 meta-analysis to estimate effect sizes.
39
40
41
42
43
44
45
46
47
48
49
50
51

52 **RESULTS**

53 The search led to the identification of 1120 papers, 1049 of which were excluded
54 based on title/abstract screening (see Figure 1). Full-text reviews were conducted on 71
55
56
57
58
59
60

Running Head: IMPACT OF DAYLIGHT SAVING TIME

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

papers, 23 of which met the study inclusion criteria. Tables 1 and 2 provide summary information on the 23 studies included in the review.

For peer review only

Running Head: IMPACT OF DAYLIGHT SAVING TIME

Table 1: Characteristics of papers included: Short-term timeframe

Author (Year)	Country	Years	Focus (sleep/light)	By season	By time of day	Population/ Outcome	Timeframe (short vs. long)	Finding (narrative)
Askenasey (1997)	Israel	1994-1996	Sleep	✓		All collisions	2 weeks before & 2 weeks after	Significant decrease in RTCs after change back to ST (autumn; attributed to sleep benefits). Technically a significant increase in RTCs after change to DST (spring) - however, 'within the chain of day-to-day increases the alleged effect of DST became non-significant'.
Conte (2007)	USA	1987-2006	Sleep	✓		All collisions excluding pedestrians	2 weeks before & 2 weeks after	Overall (combined spring & autumn) significant differences in mean daily RTCs between DST adjusted and DST unadjusted Mondays (DST 'seems to increase the number of traffic accidents')
Coren (1996)	Canada	1991-1992	Sleep	✓		All collisions	1 week before, week of, & 1 week after	The spring DST shift resulted in an average increase in RTCs of approximately 8%, whereas the fall shift resulted in a decrease in RTCs of approximately the same magnitude.
Crawley (2012)	USA	1976-2010	Sleep and light	✓		All collisions	Monday before and after	Statistically insignificant short-term effects of DST
Green (1980)	UK	1975-1977	Light	✓	Evening Only	All collisions	5 days before & after and 10 days before and after.	Based on 5-day comparison, reduction of 31% in RTCs in March (spring) and increase of 64% in October (autumn). Less marked findings for 10-

Running Head: IMPACT OF DAYLIGHT SAVING TIME

								day data.
Hicks (1998)	USA	1989-1992	Sleep	✓ ¹		All alcohol-related fatal road traffic collisions	1 week before & 1 weeks after	Alcohol-related fatalities increased significantly in the first week after the DST transition (spring and autumn combined as not different), although this returned to baseline by the second week.
Hicks (1983)	USA	1976-1978	Sleep	✓		All collisions	1 week before & 1 week after	Regardless of season of the year, DST change was associated with a significant increase in RTCs during the post-change weeks.
Huang (2010)	USA	2001-2007	Sleep and light	✓	✓	All collisions & fatal collisions	First day (Sunday) of time change compared with other Sundays	Short-term effect of DST on crashes on the morning of the first DST is not statistically significant.
Lahti (2010)	Finland	1981 - 2006	Sleep	✓		All collisions	1 week before & 1 week after	Transitions into and out of DST did not significantly increase the amount of traffic accidents.
Lambe (2000)	Sweden	1984 - 1995	Sleep	✓		All collisions	Monday before & after, & one week after	The shift to and from DST did not have measurable effects on RTC incidence.
Meyerhoff (1978)	USA	1973-1974	Light	✓	✓	All fatal collisions	Morning and evening on day of transitions in 1974 (DST) and 1973 (No DST)	DST reduced fatal RTCs by approximately 1% during several weeks at spring and autumn transitions. This effect was attributed to the spring transition, with little change during the autumn transition.
Smith (2014)	USA	2002-2011	Sleep and light	✓	✓	All fatal collisions	Unclear	5.4-7% increase in fatal RTCs immediately following spring transition.

¹ Spring and autumn transition data were combined as not statistically different from one another

Running Head: IMPACT OF DAYLIGHT SAVING TIME

								No impact in autumn.
Sood (2007)	USA	1976-2003	Sleep and light	Spring only		Fatal collisions: Pedestrians and motor vehicle occupants.	Monday before, Monday of, and Monday after.	No short-term effect, having controlled for trends in collisions trends within and across years.
Stevens (2005)	USA	1998-2000	Light	✓	✓	Fatal & nonfatal collisions involving pedestrians and motor vehicle occupants	5 working days before & after.	The immediate impact of DST, both spring and autumn, is negative, but is particularly marked for autumn transition. An increase in daylight results in a decrease in the number of pedestrian crashes.
Varughese (2001)	USA	1975-1995	Sleep	✓		All fatal collisions	Saturday/Sunday and Monday of the transition vs. same days for the week before and after.	In spring, there was a small significant increase in fatal RTCs on Monday from 78.2 to 83.5 (no impact on Saturday or Sunday). In autumn, a significant increase was found in fatalities for Sunday from 126.4 to 139.5 (no difference for Saturday or Monday).
Whittaker (1996)	UK	1983-1993	Light	✓	✓	Casualties: vehicle occupants, cyclists, pedestrians, children	1 week before & 1 week after	Overall net reduction in casualty numbers for BST periods compared to GMT. Onset of BST in spring associated with reductions in casualty numbers of 6% in morning & 11% in evening. No rise in casualties with the darker mornings. Reductions were maximal in the pedestrian (36%), cyclist (11%), and schoolchild (24%) subgroups. The change back to GMT in autumn produced an anticipated reduction (6%)

Running Head: IMPACT OF DAYLIGHT SAVING TIME

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49

									in casualties in the lighter mornings. Darker evenings associated with significant increases in casualties (4%), mainly vehicle (5%) and pedestrian (8%).
--	--	--	--	--	--	--	--	--	---

For peer review only

Running Head: IMPACT OF DAYLIGHT SAVING TIME

Table 2: Characteristics of papers included: Long-term timeframe

Author (Year)	Country	Years	Focus (sleep/light)	By season	By time of day	Population/Outcome	Timeframe (short vs. long)	Finding (narrative)
Chu (1976)	USA	1974	Light	Jan-March only	✓	All fatalities	Three months	Overall estimate of 47 fatalities saved (8%) in the first half of 1974 that can be attributed to DST. A sharply higher fatality rate during morning rush hour and a sharply lower rate in the afternoon hour.
Coate (2004)	USA	1998 and 1999	Light	✓	✓	Fatalities: Pedestrians & motor vehicle occupants	One month before & one month after	Full year DST would reduce pedestrian fatalities by 171 per year (13%), and motor vehicle occupant fatalities by 195 per year (3%). An hour later sunset would reduce evening pedestrian fatalities by about one-quarter and an hour later sunrise would increase morning fatalities by about one-third. No increased risk to school children from full year DST.
Crawley (2012)	USA	1976-2010	Both sleep and light	✓		All collisions	Thirteen weeks before & nine weeks after. Also comparison of 1987-2003 to 1976-1986	Significant fatal crash-saving effects of DST in the long run, shown particularly in the autumn test (the spring test gave little evidence either way).
Ferguson (1995)	USA	1987 - 1991	Light	✓	✓	Fatal collisions: Pedestrians & motor vehicle occupants	Thirteen weeks before & nine weeks after	An estimated 901 fewer fatal crashes (727 involving pedestrians and 174 involving vehicle occupants)

Running Head: IMPACT OF DAYLIGHT SAVING TIME

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49

								might have occurred had DST been retained year-round from 1987-1991. Benefits are smallest during the darkest winter months because the evening reduction is increasingly offset by increases during the morning. The most notable effects of changing light levels on fatal crashes were seen when light levels changed from light to twilight (crashes increased) and when twilight changed to light (crashes decreased).
Huang (2010)	USA	2001-2007	Both sleep and light	✓	✓	All collisions and fatal collisions	8 weeks before & after	DST, all else equal, is associated with fewer RTCs and fatal RTCs for most day parts (except 9am-3pm).
Meyerhoff (1978)	USA	1973-1974	Light	✓	✓	All fatal collisions	Jan-Feb and March-April 1974 (DST) and Jan-Feb and March-April 1973 (No DST) (long-term).	A net reduction of about 0.7% during the DST period, March and April 1974, compared to the non-DST period. March and April 1973, but little net DST effect on fatal accidents in winter. A marked decrease in evening fatalities is observed, but the morning increase is not seen as anticipated.
Sood (2007)	USA	1976-2003	Both sleep and light	Spring only		Fatal collisions: Pedestrians and motor vehicle occupants.	13 weeks before & 8 weeks after	Long-term reduction of 8-11% in RTCs involving pedestrians, and 6-10% in RTCs involving vehicle

Running Head: IMPACT OF DAYLIGHT SAVING TIME

								occupants.
Sullivan (2003 & 2004)	USA	1987-2001	Light	Autumn only	Evening only	Fatal collisions: Motor vehicle occupants only	5 weeks before & after	Rear-end collisions change from an average count of about 13 crashes in the light (DST) to an average of 37 in the dark (ST). Impact of light on crash risk varies across rear-end collision types.
Sullivan (2002)	USA	1987-1997	Light	✓	✓	Fatal collisions: Pedestrians and motor vehicle occupants	9 weeks before and after	Overall, pedestrian fatalities 3 to 6.75 times more likely in darkness (ST) than in daylight (DST), while other crashes were only marginally more likely in darkness Spring am: Twilight shows a decline in crashes from week-8 (39 crashes) to week-1 (8 crashes); at the changeover, when the period is returned to darkness, the crash level rises again Spring pm: the crash frequency is high during the dark period just before the DST changeover, and drops to 54, the week after the changeover and declines more the following week to 32 Autumn am: 79 crashes before the transition and 29 after Autumn pm: In the week before the transition there were 65 crashes, in the following week there were 227, an increase of three and

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49

Running Head: IMPACT OF DAYLIGHT SAVING TIME

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49

								a half times.
Sullivan (2001)	USA	1987-1997	Light	✓	Evening only	Fatal collisions: Pedestrians	3 weeks before and after	Pedestrian fatalities 4.14 times more likely in darkness (DST) than in daylight (ST). Interaction between light and alcohol use.
Sullivan (2007)	USA	FARS= 1987-2004; NCDO T=1991-1999.	Light	✓	Evening only	Fatal & nonfatal collisions: Pedestrian (child, adult, elderly) and motor vehicle occupants	5 weeks before and after	Fatal crashes involving pedestrians, animals, and other motor vehicles showed the most reliable increases in risk in low light levels (ST). Children show a reliably greater risk in darkness, but this risk is much smaller than the risk observed for adult and elderly pedestrians – which is nearly 7 times greater in darkness. Even when the data are not separated by age, the apparent increase in pedestrian risk in the dark is very strong.

Running Head: IMPACT OF DAYLIGHT SAVING TIME

1
2
3 Data for a majority of studies (74%) were from the United States (US), with 9% of
4 studies based on DST in the UK. Other countries included were Canada, Finland, Israel, and
5 Sweden (total 17% of studies). Years captured in the analyses ranged from 1973 to 2011.
6
7

8
9
10 Sixteen of the included studies (70%) investigated the short-term effects of DST by
11 examining the period immediately (two weeks or less) before and after the DST shift. Of these
12 papers, 50% focused on the effects of sleep disruptions caused by the DST shift (see next
13 section for more detail), 25% focused on light levels and 25% looked at both sleep and light
14 (see Table 1). Eleven of the studies (48%) examined the overall or long-term effects of DST,
15 focusing on changes in light levels that result from DST. Their timeframes ranged from 3 to
16 13 weeks around the DST transitions (see Table 2). Note that four studies examined both
17 short- and long-term effects, and these analyses were treated separately in the synthesis.
18
19

20
21 A minority (31%) of the short-term analyses distinguished between morning and
22 evening risk, while a majority (55%) of the long-term analyses did so. Conversely, almost all
23 (94%) of the short-term analyses separated spring from autumn DST transitions, while less
24 than half (45%) of the long-term studies made this distinction. Nine of the 23 studies (39%)
25 provided analyses by road user (e.g. pedestrian vs. motor vehicle user).
26
27

28 **What is the impact of DST on road traffic collisions, injuries and fatalities?**

29 Short-term impact

30
31 For the transition into DST (i.e. the spring shift), we would anticipate a reduction in
32 road traffic collisions due to the extended daylight during evening journeys. However,
33 findings relating to the spring DST shift were inconsistent across studies. Almost one-in-five
34 studies (19%) reported a reduction in collisions, 44% reported an increase in collisions and
35 38% reported no change. Increases were largely attributed to the fact that the spring transition
36 results in a 23-hour day, creating a 'missing' hour and leading to sleep disruption (latency and
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

Running Head: IMPACT OF DAYLIGHT SAVING TIME

1
2
3 duration). This has been reported to have a negative impact on sleep quality for up to two
4
5 weeks after the transition [13 14].
6

7
8 An examination of the short-term change in road traffic collisions around the transition
9
10 back to standard time (ST) in autumn may offer a purer test of the impact of DST on road
11
12 safety. This transition results in improved lighting in the morning, but a reduction in the
13
14 evening, which should lead to an increase in road traffic collisions. Since this transition does
15
16 not lead to a 'missing hour', sleep effects should be less pronounced. Fifteen of the short-term
17
18 studies provided relevant data, and findings indicated that, contrary to expectation, the autumn
19
20 transition was associated with either a reduction in road traffic collisions or no change.
21
22

23 It is worth noting that a majority of these short-term studies focused on the effects of
24
25 sleep deprivation on road traffic collisions, particularly during the spring transition, rather
26
27 than exploring the potential impact of a permanent shift in time zones on road safety
28
29 outcomes.
30

31 Long-term impact 32

33
34 Eleven of the 23 studies examined the overall or longer-term impact (>2 weeks) of
35
36 DST on road safety outcomes. All of these studies reported a reduction in collisions, injuries
37
38 and fatalities associated with DST. The overall magnitude of this effect, though hard to
39
40 estimate given the variability in study approaches and analyses, tended to be small. Huang and
41
42 Levinson, for example, report that 'a day in DST, all else equal, is associated with about
43
44 0.09% fewer crashes than a day in ST [standard time]' [15, p.519]. Meyerhoff reported a net
45
46 reduction of 0.7% of fatal collisions during 2 months in DST, compared to 2 months in ST,
47
48 and little overall impact of DST in winter months [16].
49
50

51
52 Importantly, there was an observed increase in collisions during the morning hours in
53
54 DST (although not in all studies; see 12), but it was noted that the overall benefit to road
55
56
57
58
59
60

Running Head: IMPACT OF DAYLIGHT SAVING TIME

1
2
3 safety tended to outweigh the morning risks. Several studies extrapolated from the findings of
4
5 their analyses to the impact of retaining DST year-round.
6

7
8 **What is the impact of DST on road traffic collisions, injuries and fatalities for different**
9
10 **types of road users (e.g. vehicle occupants Vs pedestrians, cyclists, etc.)?**

11
12 Of the 9 studies that analysed DST effects on different types of road users, the
13
14 beneficial effects of DST were most pronounced for pedestrians. In one study, the estimated
15
16 effects of retaining DST approximated 13% fewer pedestrian fatalities, and 3% fewer vehicle
17
18 occupant fatalities [17]. The collision risk posed to pedestrians following the transition back to
19
20 ST was found to be greater than that for motor vehicle occupants. Ferguson *et al*, for example,
21
22 reported a greater collision risk for pedestrians than for motor vehicle occupants, following
23
24 the transition from DST to ST. Specifically, they found the change from daylight to twilight to
25
26 be associated with a 300% increase in fatal collisions involving pedestrians. Of the 901 fewer
27
28 fatal collisions they estimate would have occurred from 1987 to 1991, had DST operated year-
29
30 round, 727 of these would have involved pedestrians, while 174 would have involved motor
31
32 vehicle occupants [9]. Whittaker [18] reported that the onset of DST in spring was associated
33
34 with a reduction in casualties that was particularly pronounced for pedestrians (36%) and
35
36 cyclists (11%).
37
38

39
40 Sullivan and Flannagan found 4.1 times as many pedestrian fatalities in darkness
41
42 (during ST) compared to daylight (during DST), and 1.3 times as many motor vehicle
43
44 collisions in darkness, compared to daylight. Thus, although darkness increased collision risk
45
46 for both groups of road users, the risks posed were greatest for pedestrians [19]. Sood and
47
48 Ghosh reported an overall long-term reduction in collisions involving both pedestrians (8 to
49
50 11%) and motor vehicle occupants (6 to 10%). They noted that the 'saving' in collisions
51
52 peaked in the third (for pedestrians) and fourth (for motor vehicle occupants) weeks after DST
53
54 onset [20].
55
56
57
58
59
60

Running Head: IMPACT OF DAYLIGHT SAVING TIME

1
2
3 Again, however, it is important to note that the impact of DST on pedestrian risk may
4 differ from morning to evening. Coate and Markowitz estimated that year-round DST would
5 reduce pedestrian fatalities in the evening by one-quarter, but increase those in the morning by
6 one-third. They conclude that, since pedestrian activity is higher in the evening compared to
7 the morning, year-round DST would reduce overall pedestrian fatalities by 13% [17].
8
9
10
11
12
13

14 DISCUSSION

15
16
17 The most valid evidence from the DST literature that can be used to inform the CET
18 debate is that pertaining to the *short-term* impact of shifting to, and from, DST. These
19 analyses should allow us to isolate the ‘light’ effect, given that there should be minimal
20 changes in extraneous factors. Findings from these studies were inconsistent, with results
21 suggesting that shifting light by adjusting time can have positive or negative road safety
22 consequences, or result in no change. In addition, most studies did not extrapolate findings to
23 hypothetical conditions under a more permanent change in time. Thus, the short-term
24 evidence cannot support or refute the assertion that a move to CET will have a road safety
25 benefit in the UK and RoI.
26
27
28
29
30
31
32
33
34
35
36
37

38 The long-term findings were more consistent, and the overall impact of DST was
39 positive (i.e. risk-reducing) in all 11 long-term studies included. We would stress that this
40 reduction cannot be attributed solely to DST, as a variety of risk factors for road collisions
41 vary in the long-term, including traffic flow and weather conditions. Given the diverse range
42 of statistical approaches adopted and the range of assumptions made, we did not statistically
43 combine findings through meta-analysis, and cannot therefore estimate the overall magnitude
44 of the effect. In addition, it is important to note that all long-term studies were based on data
45 from the US. As such, while we acknowledge that positive findings from the long-term
46 analyses of DST, we would argue that these findings (i) may be attributable to factors other
47
48
49
50
51
52
53
54
55
56
57
58
59
60

Running Head: IMPACT OF DAYLIGHT SAVING TIME

1
2
3 than light and (ii) are of questionable validity in the context of a change in time zones in other
4
5 jurisdictions.
6

7
8 In summary, the picture emerging from this review is complex. Specifically, we found
9
10 that the short-term effects of DST are likely to be small and potentially negative or positive
11
12 depending on time of year and day. The long-term effects tend to be positive, but may be
13
14 attributable to factors other than light. Overall, the evidence from this review cannot be used
15
16 to support the assertion that a permanent shift in light from morning to evening will have a
17
18 road safety benefit. These findings have implications for on-going debates in the UK, RoI and
19
20 elsewhere, where changes in time-zones are being considered.
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

Running Head: IMPACT OF DAYLIGHT SAVING TIME

Author Contribution Statement

KS conceived the systematic review and supervised the research. RC was primarily responsible for database searching and reviewing texts for inclusion. KS and RC both contributed to the data extraction, data analysis, and manuscript drafting.

Funding

This paper is based on a report commissioned by the Road Safety Authority of Ireland

Data Sharing Statement

The datasets supporting the conclusions of this article are available on request from the corresponding author.

Licence to BMJ Publishing Group Limited

I Kiran M. Sarma The Corresponding Author of this article contained within the original manuscript which includes any diagrams & photographs within and any related or stand alone film submitted (the Contribution”) has the right to grant on behalf of all authors and does grant on behalf of all authors, a licence to the BMJ Publishing Group Ltd and its licencees, to permit this Contribution (if accepted) to be published in the BMJ and any other BMJ Group products and to exploit all subsidiary rights, as set out in our licence set out at:

<http://www.bmj.com/about-bmj/resources-authors/forms-policies-and-checklists/copyright-open-access-and-permission-reuse>. I am one author signing on behalf of all co-owners of the Contribution.

Conflict of Interests

No, there are no competing interests

References

1. Schiavenza M. China Only Has One Time Zone—and That's a Problem. Secondary China Only Has One Time Zone—and That's a Problem 2013. <http://www.theatlantic.com/china/archive/2013/11/china-only-has-one-time-zone-and-thats-a-problem/281136/>.
2. BBC. Russian clocks go back for last time. Secondary Russian clocks go back for last time 2014. <http://www.bbc.co.uk/news/world-europe-29773559>.
3. BBC. North Korea's new time zone to break from 'imperialism'. Secondary North Korea's new time zone to break from 'imperialism' 2015. <http://www.bbc.co.uk/news/world-asia-33815049>.
4. Tadeo M. Breaking With Old Politics May Begin With Clock Change in Spain. Secondary Breaking With Old Politics May Begin With Clock Change in Spain 2016. <http://www.bloomberg.com/news/articles/2016-02-25/breaking-with-old-politics-may-begin-with-clock-change-in-spain>.
5. ROSPA. Single Double British Summertime Factsheet 2014.
6. Sullivan JM, Flannagan MJ. Determining the potential safety benefit of improved lighting in three pedestrian crash scenarios. *Accident Analysis and Prevention* 2007;**39**(3):638-47 doi: 10.1016/j.aap.2006.10.010[published Online First: Epub Date]].
7. Broughton J, Stone M. *A new assessment of the likely effects on road accidents of adopting SDST*: Transport Research Laboratory, 1998.
8. Adams J, White M, Heywood P. Year-round daylight saving and serious or fatal road traffic injuries in children in the north-east of England. *Journal of Public Health* 2005;**27**(4):316-17 doi: 10.1093/pubmed/fdi047[published Online First: Epub Date]].

- 1
2
3 9. Ferguson SA, Preusser DF, Lund AK, et al. Daylight Saving Time and Motor Vehicle
4
5 Crashes: The Reduction in Pedestrian and Vehicle Occupant Fatalities. American
6
7 Journal of Public Health 1995;**85**(1):92-95
8
- 9
10 10. Plainis S, Murray IJ, Pallikaris IG. Road traffic casualties: understanding the night-time
11
12 death toll. Injury Prevention 2006;**12**(2):125-28 doi:
13
14 10.1136/ip.2005.011056[published Online First: Epub Date]].
15
- 16
17 11. Harrison Y. The impact of daylight saving time on sleep and related behaviours. Sleep
18
19 Medicine Reviews 2013;**17**(4):285-92 doi: 10.1016/j.smr.2012.10.001[published
20
21 Online First: Epub Date]].
22
- 23
24 12. Popay J, Roberts H, Sowden A, et al. Guidance on the conduct of narrative synthesis in
25
26 systematic reviews. ESRC methods programme 2006;**15**(1):047-71
27
- 28
29 13. Lahti TA, Leppämäki S, Lönnqvist J, et al. Transitions into and out of daylight saving
30
31 time compromise sleep and the rest-activity cycles. BMC physiology 2008;**8**(1):1
32
- 33
34 14. Kantermann T, Juda M, Merrow M, et al. The human circadian clock's seasonal
35
36 adjustment is disrupted by daylight saving time. Current Biology 2007;**17**(22):1996-
37
38 2000 doi: 10.1016/j.cub.2007.10.025[published Online First: Epub Date]].
39
- 40
41 15. Huang A, Levinson D. The effects of daylight saving time on vehicle crashes in
42
43 Minnesota. Journal of Safety Research 2010;**41**(6):513-20 doi:
44
45 10.1016/j.jsr.2010.10.006[published Online First: Epub Date]].
46
- 47
48 16. Meyerhoff NJ. The influence of daylight saving time on motor vehicle fatal traffic
49
50 accidents. Accident Analysis and Prevention 1978;**10**(3):207-21
51
- 52
53 17. Coate D, Markowitz S. The effects of daylight and daylight saving time on US pedestrian
54
55 fatalities and motor vehicle occupant fatalities. Accident Analysis and Prevention
56
57 2004;**36**(3):351-57 doi: 10.1016/s0001-4575(03)00015-0[published Online First: Epub
58
59 Date]].
60

- 1
2
3 18. Whittaker J. An investigation into the effects of British Summer Time on road traffic
4 accident casualties in Cheshire. *Journal of accident & emergency medicine*
5
6 1996;**13**(3):189-92
7
8
9
10 19. Sullivan JM, Flannagan M. Characteristics of pedestrian risk in darkness. 2001
11
12 20. Sood N, Ghosh A. The short and long run effects of daylight saving time on fatal
13 automobile crashes. *The BE Journal of Economic Analysis & Policy* 2007;**7**(1)
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

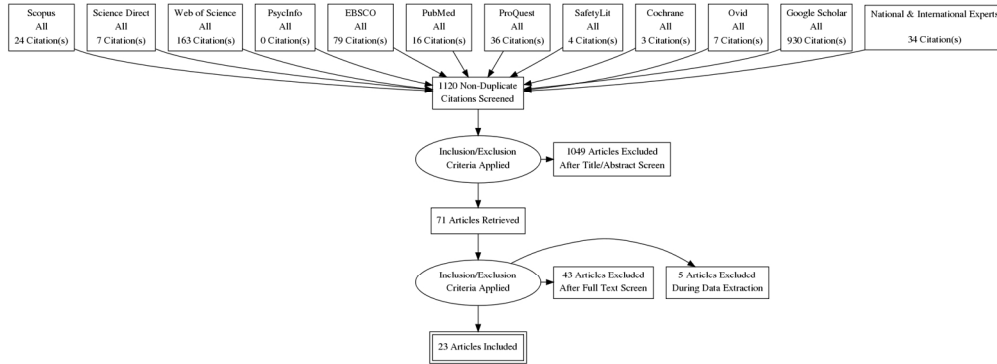


Figure 1: PRISMA flow chart
Figure 1
661x240mm (72 x 72 DPI)

Peer review only



PRISMA 2009 Checklist

Section/topic	#	Checklist item	Reported on page #
TITLE			
Title	1	Identify the report as a systematic review, meta-analysis, or both.	1
ABSTRACT			
Structured summary	2	Provide a structured summary including, as applicable: background; objectives; data sources; study eligibility criteria, participants, and interventions; study appraisal and synthesis methods; results; limitations; conclusions and implications of key findings; systematic review registration number.	2
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of what is already known.	5
Objectives	4	Provide an explicit statement of questions being addressed with reference to participants, interventions, comparisons, outcomes, and study design (PICOS).	5-6
METHODS			
Protocol and registration	5	Indicate if a review protocol exists, if and where it can be accessed (e.g., Web address), and, if available, provide registration information including registration number.	N/A
Eligibility criteria	6	Specify study characteristics (e.g., PICOS, length of follow-up) and report characteristics (e.g., years considered, language, publication status) used as criteria for eligibility, giving rationale.	6
Information sources	7	Describe all information sources (e.g., databases with dates of coverage, contact with study authors to identify additional studies) in the search and date last searched.	6
Search	8	Present full electronic search strategy for at least one database, including any limits used, such that it could be repeated.	6
Study selection	9	State the process for selecting studies (i.e., screening, eligibility, included in systematic review, and, if applicable, included in the meta-analysis).	6
Data collection process	10	Describe method of data extraction from reports (e.g., piloted forms, independently, in duplicate) and any processes for obtaining and confirming data from investigators.	7
Data items	11	List and define all variables for which data were sought (e.g., PICOS, funding sources) and any assumptions and simplifications made.	7
Risk of bias in individual studies	12	Describe methods used for assessing risk of bias of individual studies (including specification of whether this was done at the study or outcome level), and how this information is to be used in any data synthesis.	N/A
Summary measures	13	State the principal summary measures (e.g., risk ratio, difference in means).	N/A
Synthesis of results	14	Describe the methods of handling data and combining results of studies, if done, including measures of consistency (e.g., I^2) for each meta-analysis.	7



PRISMA 2009 Checklist

Section/topic	#	Checklist item	Reported on page #
Risk of bias across studies	15	Specify any assessment of risk of bias that may affect the cumulative evidence (e.g., publication bias, selective reporting within studies).	N/A
Additional analyses	16	Describe methods of additional analyses (e.g., sensitivity or subgroup analyses, meta-regression), if done, indicating which were pre-specified.	N/A
RESULTS			
Study selection	17	Give numbers of studies screened, assessed for eligibility, and included in the review, with reasons for exclusions at each stage, ideally with a flow diagram.	7
Study characteristics	18	For each study, present characteristics for which data were extracted (e.g., study size, PICOS, follow-up period) and provide the citations.	8-15
Risk of bias within studies	19	Present data on risk of bias of each study and, if available, any outcome level assessment (see item 12).	N/A
Results of individual studies	20	For all outcomes considered (benefits or harms), present, for each study: (a) simple summary data for each intervention group (b) effect estimates and confidence intervals, ideally with a forest plot.	N/A
Synthesis of results	21	Present results of each meta-analysis done, including confidence intervals and measures of consistency.	N/A
Risk of bias across studies	22	Present results of any assessment of risk of bias across studies (see Item 15).	N/A
Additional analysis	23	Give results of additional analyses, if done (e.g., sensitivity or subgroup analyses, meta-regression [see Item 16]).	N/A
DISCUSSION			
Summary of evidence	24	Summarize the main findings including the strength of evidence for each main outcome; consider their relevance to key groups (e.g., healthcare providers, users, and policy makers).	19
Limitations	25	Discuss limitations at study and outcome level (e.g., risk of bias), and at review-level (e.g., incomplete retrieval of identified research, reporting bias).	19
Conclusions	26	Provide a general interpretation of the results in the context of other evidence, and implications for future research.	19-20
FUNDING			
Funding	27	Describe sources of funding for the systematic review and other support (e.g., supply of data); role of funders for the systematic review.	20

From: Moher D, Liberati A, Tetzlaff J, Altman DG, The PRISMA Group (2009). Preferred Reporting Items for Systematic Reviews and Meta-Analyses: The PRISMA Statement. PLoS Med 6(7): e1000097. doi:10.1371/journal.pmed1000097

For more information, visit: www.prisma-statement.org.

BMJ Open

Impact of daylight saving time on road traffic collision risk: a systematic review

Journal:	<i>BMJ Open</i>
Manuscript ID	bmjopen-2016-014319.R1
Article Type:	Research
Date Submitted by the Author:	16-Feb-2017
Complete List of Authors:	Carey, Rachel; University College London, Department of Clinical, Educational & Health Psychology Sarma, Kiran; National University of Ireland, Galway,
Primary Subject Heading:	Public health
Secondary Subject Heading:	Evidence based practice, Health policy
Keywords:	Road safety, Daylight saving time, Collision risk, Systematic review

SCHOLARONE™
Manuscripts

Peer Review Only

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

**Impact of daylight saving time on road traffic collision risk: a
systematic review**

Rachel N. Carey¹ (PhD) & Kiran M. Sarma*² (PhD)

¹Department of Clinical, Educational and Health Psychology, University College London, 1-
19 Torrington Place, London WC1E 7HB, United Kingdom.

² School of Psychology, National University of Ireland Galway, University Road, Galway,
Ireland.

Email: kiran.sarma@nuigalway.ie; Telephone: +353 91 495715

*Corresponding Author

Word Count: 4358

Abstract

Background: Bills have been put forward in the United Kingdom and Republic of Ireland proposing a move to Central European Time (CET). Proponents argue that such a change will have benefits for road safety, with daylight being shifted from the morning, when collision risk is lower, to the evening, when risk is higher. Studies examining the impact of daylight saving time (DST) on road traffic collision risk can help inform the debate on the potential road safety benefits of a move to CET. The objective of this systematic review was to examine the impact of DST on collision risk.

Methods: Major electronic databases were searched, with no restrictions as to date of publication (the last search was performed in January 2017). Access to unpublished reports was requested through an international expert group. Studies that provided a quantitative analysis of the effect of DST on road safety-related outcomes were included. The primary outcomes of interest were road traffic collisions, injuries and fatalities.

Findings: Twenty-four studies met the inclusion criteria. Seventeen examined the short-term impact of transitions around DST and 12 examined long-term effects. Findings from the short-term studies were inconsistent. The long-term findings suggested a positive effect of DST. However, this cannot be attributed solely to DST, as a range of road collision risk factors vary over time.

Interpretation: The evidence from this review cannot support or refute the assertion that a permanent shift in light from morning to evening will have a road safety benefit.

Keywords: Systematic review, road safety, daylight saving time, collision risk.

Article Summary

Strengths and limitations of this study

- This review draws together evidence of the impact of shifting time-zones on road traffic collision risk and is, to our knowledge, the first systematic review that can inform current debates on time-zone changes.
- A key strength of this review is the examination of collision risk across different types of road users and time of day, reflecting the complex array of factors that are implicated in the relationship between light and collision risk.
- Studies selected varying time periods around DST transitions for analyses, and used a range of analytic and statistical approaches. We were therefore unable to combine the findings through meta-analysis.
- The long-term findings reported in this review are less relevant to the review question than the short-term findings, since a range of risk factors for road traffic collisions vary in the long-term (e.g. traffic flow and weather conditions).

Introduction

In recent years, Bills such as the *Brighter Evenings Bill* have been put before parliaments in the United Kingdom (UK) and Republic of Ireland (RoI) that, if enacted, would result in these jurisdictions changing time-zone from Greenwich Mean Time (GMT) to Central European Time (CET). These jurisdictions would not be the first to adjust time-zones. China historically changed time zones within its borders [1] and, more recently, Russia [2] and North Korea [3], among others, have experimented with time-zone changes. Currently, there are a number of countries, including Spain [4], contemplating similar shifts.

For the UK and RoI, the change would impact on approximately 70 million people. In practice, it would mean that the sun would rise and set one hour later than at present, leading to darker mornings and brighter evenings. Proponents of the Bills argue that such a change would have economic benefits, arising from the alignment of the working day across neighbouring economic partners, and societal benefits, including a reduction in road traffic collisions, injuries and fatalities [5].

The assertion that a move to CET would have a positive impact on road safety is rooted in the relationship between light and collision risk. It has been argued that road traffic collision risk is at its highest in the late afternoon and evening hours (c. 15.00 to 19.00) and that, on some level, this arises due to the interaction between deteriorating lighting conditions and other risk factors, including driver fatigue [6 7]. To the extent that evening collision risk derives from poor light, shifting an hour of daylight from the morning, when collision risk is lower, to the evening, when collision risk is higher, should lead to an overall net reduction in road traffic collisions [5 8 9]. This should be particularly marked during the autumn and winter months when the evenings are darker and weather conditions less favourable for road users [5].

1
2
3 This argument has found some support in the empirical literature. Broughton and
4 Stone, for example, have produced an authoritative study on the likely effects on road
5 collisions of adopting Single/Double Summer Time (SDST, i.e. CET) year-round. Using
6 mathematical modelling procedures to estimate casualty incidence, they estimated that a move
7 to CET would lead to an overall reduction in fatalities of between 2.6 and 3.4%, and a
8 reduction in serious injuries of 0.7% [7]. The UK's Royal Society for the Prevention of
9 Accidents (RoSPA) recently drew similar conclusions, arguing that any increase in a morning
10 collision peak will be 'more than off-set by the reduction in the higher evening peak' [5, p.1].

11
12
13
14
15
16
17
18
19
20
21 The overall trends relating to collisions across time of day appear, at first glance, to
22 support some of the core assumptions behind the CET argument. However, the extent to
23 which collision risk is actually impacted by shifting light and time is unclear, and difficult to
24 expose to scientific enquiry for a number of reasons. First, most of the UK studies on CET are
25 based on data derived from the 1968-1971 British Standard Time (BST) experiment, during
26 which the UK remained in Daylight Saving Time (DST) year-round. As noted by the
27 Transport Research Laboratory [7], 'conditions have changed since the end of the experiment
28 and the results cannot be applied directly to current conditions' (p. 3). Specifically, there have
29 been substantial changes in traffic levels, road infrastructure and road user behaviour in the
30 past five decades that mean the 1968-1971 experiment may be of limited relevance today.

31
32
33
34
35
36
37
38
39
40
41
42
43 Second, evidence suggests that light is rarely a direct cause of collisions. Instead, light
44 and darkness tend to compound more direct causal factors. For example, driver performance
45 deteriorates under poor lighting conditions, due to diminished visual reaction times and
46 impeded ability to process core information like critical stopping distances. Collisions in this
47 context are caused by driver error - error that can occur under both ambient and dark
48 conditions, but which is compounded under the latter [10]. Similarly, light can interact with
49 environmental factors, like rain, frost and snow, to inflate crash risk.

1
2
3 The impact of a move to CET is not easily estimated, given the complex array of
4 factors implicated in collisions. One method for examining its potential impact is to look at
5 transitions into and out of daylight saving time (DST). DST refers to the practice of adjusting
6 the clock time to create extra daylight during periods of waking activity [11]. In the northern
7 hemisphere, clocks are set forward by one hour in spring, providing an extra hour of daylight
8 in the evenings, and revert back to standard time (ST) in the autumn, leading to an extra hour
9 of daylight in the mornings. DST shifts provide a naturalistic experiment that can yield
10 estimates as to the association between light and collisions. Particularly in the short-term
11 (typically 1-2 weeks around the transitions), these estimates can be considered to account for
12 the influence of traffic and pedestrian-flow, which are believed to be relatively stable over
13 short periods of time. Longer term studies (typically 3 -13 weeks around the transition) may
14 also provide insights, provided other explanatory variables have been statistically controlled
15 for.

16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32 Several studies have empirically investigated the short-term and long-term impact of
33 DST on road safety. However, these studies have taken place in different jurisdictions, and
34 used a variety of statistical and methodological approaches. Given that a key argument
35 currently being put forward for a move to CET is the potential road safety benefit, there is a
36 need for these studies to be systematically synthesised. Such a synthesis would allow us to
37 extrapolate key lessons from the literature base, to address over-reliance on individual studies,
38 and to overcome any tendency to selectively attend to evidence that supports a particular
39 position relating to shifting time-zones. This paper summarises the findings of the first
40 systematic review of the literature relating to the impact of DST on road safety.

41
42
43
44
45
46
47
48
49
50
51 The review addressed the following research questions:

- 52 1. What is the impact of DST on road traffic collisions, injuries and fatalities on morning
53 vs. evening risk?
54
55
56
57
58
59
60

- 1
2
3 2. What is the impact of DST on different types of road users (e.g. vehicle occupants vs.
4 pedestrians, cyclists, etc.)?
5
6

7 **METHODS**

8 **Search Strategy and Selection Criteria**

9
10 We conducted a systematic review of the literature pertaining to the impact of DST on
11 road safety outcomes. Studies reporting a quantitative analysis, using primary data, of the
12 effect of DST on road safety-related outcomes (i.e. road traffic collisions, injuries and
13 fatalities) were included in the review. Only studies published in English were included in the
14 final review. We excluded qualitative studies, opinion pieces, and newspaper/magazine
15 articles, where no primary data were analysed. Studies were also excluded if they artificially
16 constructed a change in lighting conditions (e.g. in a laboratory experiment), if potential
17 effects of DST were discussed but not controlled for in the analysis (e.g. if studies drew
18 conclusions about DST based on their findings but did not specifically examine DST
19 transitions in their analyses), if the analysis did not specifically focus on the impact of DST,
20 and/or if the analysis related to time-zone changes and not DST. Studies involving all
21 populations (i.e. all types of road users) were included.
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37

38 Papers were identified by conducting computerised searches of the Cochrane, EBSCO,
39 Google Scholar, PsycInfo, PubMed, SafetyLit, Science Direct, Scopus, Web of Science,
40 TRID, Lilacs, and Scielo databases. We also searched ProQuest for 'grey' literature.
41
42 Keywords informed by pilot scoping exercises, included daylight saving, DST, time change,
43 road safety, road traffic collision, crash, accident, fatalities, and injuries (e.g. "daylight
44 saving*" OR DST OR "time change" AND "road safety" OR "road traffic" OR collision OR
45 crash OR accident); see Supplementary File 1 for the full search strategy for one database.
46
47 The last search of these databases was performed on January 18th, 2017. A request for papers
48 was also sent to the International Traffic Safety Data and Analysis Group. Representatives
49
50
51
52
53
54
55
56
57
58
59
60

1
2
3 from more than 30 road safety agencies world-wide, as well as academic institutions and
4
5 members of the automobile industry, are members of the group. The review questions and
6
7 search methodology were devised following consultation with the Road Safety Authority of
8
9 Ireland, as a core user of road safety research. Collision victims, their families, and other road
10
11 safety stakeholders were not invited to contribute to the design or execution of the study.
12
13

14 **Data Collection and Analysis**

15
16 One reviewer reviewed titles and abstracts of all returned papers to identify potentially
17
18 relevant studies, and reliability with a second reviewer (who reviewed 15% of these) was high
19
20 (Kappa = 0.8). Discrepancies were resolved through discussions between the reviewers. On
21
22 the basis of the abstract, full texts were retrieved for all studies that (i) met the inclusion
23
24 criteria or (ii) did not provide enough information in the abstract to determine eligibility. One
25
26 reviewer reviewed all full-texts to determine eligibility for inclusion and this was checked, for
27
28 15% of studies, by a second reviewer (Kappa = 1.00). Where multiple papers referred to the
29
30 same analysis on the same data-set, these were included in the review as one study only.
31
32
33

34 Data extraction was conducted by two reviewers using a standardised form. The
35
36 following data was extracted from studies: location, year(s) captured, timeframe captured,
37
38 source of road safety data utilised, research question(s), variable(s) included in analysis,
39
40 outcome(s), findings, whether the analyses related to short- or long-term impact, type of
41
42 statistical analyses used, and whether or not the analyses were broken down by (i) road user,
43
44 (ii) time of day (i.e. morning vs. evening), and (iii) time of year (i.e. spring DST change Vs
45
46 autumn DST change). We extracted data relating to short- and long-term impact separately,
47
48 where available. Examining short-term changes in collisions following DST transitions is
49
50 thought to control for factors, such as traffic volume, that can vary over longer periods of
51
52 time. We also extracted information relating to spring and autumn transitions separately,
53
54 where available, in part because the spring transition leads to a shortening of the transition
55
56
57
58
59
60

1
2
3 day by one hour, which can impact on sleep duration and latency [12 13]. The autumn
4
5 transition, conversely, adds an extra hour to the transition day and short-term collision trends
6
7 are less likely to be linked to sleep duration and latency.
8

9
10 It is important to note that we attempted to extract information that would provide an
11
12 estimate of the size of the collision datasets used in the papers. However, this proved
13
14 extremely difficult as this information was often not explicitly provided by the authors; in
15
16 some cases we were left to derive estimates from graphical representations rather than tabular
17
18 data. To compound this issue, where incidence *was* reported, varying units of measurement
19
20 (e.g. weeks, days, parts of days, etc.) were often used, that could not reliably be reconciled
21
22 into a standard reporting unit.
23

24
25 Data were synthesised using narrative synthesis [14]. An initial scoping of the
26
27 literature-base suggested that studies used a range of statistical approaches, and made varying
28
29 statistical assumptions, and as such we did not seek to combine the findings through meta-
30
31 analysis to estimate overall effect sizes.
32

33 34 **Quality Assessment**

35
36 The quality of the papers included in the review was assessed using a bespoke set of
37
38 quality assessment criteria [15]. These criteria were identified by the research team to capture
39
40 the extent to which the information provided answered the review questions. As such, the
41
42 quality assessment is not an assessment of the strengths and limitations of the papers *per se*,
43
44 but rather the extent to which they can inform current deliberations on the potential road
45
46 safety value of changing time-zones. The 'ideal' paper, in terms of the review questions,
47
48 would a) use an official road safety database (e.g. maintained by a statutory agency), b) report
49
50 both short and long term analyses, c) examine morning and evening trends, d) explore both
51
52 spring and autumn transitions, e) probe the impact of light transitions on a range of road users
53
54 (e.g. pedestrians, cyclists, vehicle occupants, adults, children etc.), f) report statistics that
55
56
57
58
59
60

1
2
3 could facilitate a meta-analysis, g) report data on factors, such as traffic volume, that could
4
5 explain (in whole or part) any trends that emerged, and f) focus specifically on the impact of
6
7 light (rather than sleep) on road safety. Each study was coded as 'met criterion', 'did not meet
8
9 the criterion' or 'unclear'. To make these assessments, first, five papers were randomly
10
11 selected and reviewed by two researchers (RC & KS) independently. As their inter-rater
12
13 reliability was > 95%, the remaining papers were quality-assessed by one researcher (i.e. each
14
15 coder coded 9-10 papers).
16
17

18 19 **RESULTS**

20
21 The search led to the identification of 1411 non-duplicate papers, 1314 of which were
22
23 excluded based on title/abstract screening (see Figure 1). Full-text reviews were conducted on
24
25 97 papers, 24 of which met the study inclusion criteria. There were eight papers published in a
26
27 language other than English, on which abstract and/or full-text review could not be performed;
28
29 these were excluded from the review in-line with the inclusion/exclusion criteria. Tables 1 and
30
31
32
33 2 provide summary information on the 24 studies included in the review.
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

Table 1: Characteristics of papers included: Short-term timeframe

Author (Year)	Country	Years	Focus (sleep/light)	By season	By time of day (morning/evening).	Population & Outcome	Timeframe	Finding (narrative)
Askenasey [16] (1997)	Israel	1994-1996	Sleep	✓	X	All collisions.	2 weeks before & 2 weeks after.	Spring: Technically a significant increase in RTCs after change to DST - however, 'within the chain of day-to-day increases the alleged effect of DST became non-significant'. Autumn: Significant decrease in RTCs after change back to ST (attributed to sleep benefits).
Conte [17] (2007)	USA	1987-2006	Sleep	✓	X	All collisions excluding pedestrians.	2 weeks before & 2 weeks after.	Significant differences in mean daily RTCs between DST adjusted and DST unadjusted Mondays (DST 'seems to increase the number of traffic accidents'). Note: Distinction between spring & autumn not clear from inferential statistics reported.
Coren [18] (1996)	Canada	1991-1992	Sleep	✓	X	All collisions.	1 week before, week of, & 1 week after.	Spring: The spring DST shift resulted in an average increase in RTCs of approx. 8% Autumn: The autumn shift resulted in a decrease in RTCs of approximately the same magnitude.
Crawley [19] (2012)	USA	1976-2010	Sleep and light	✓	X	All collisions.	Monday before and after.	Spring & Autumn: No statistically significant short-term effects of DST.
Green [20] (1980)	UK	1975-1977	Light	✓	Evening Only	All collisions.	5 days before & after and 10 days before and after.	Spring: Based on 5-day comparison, reduction of 31% in RTCs in March Autumn: Increase of 64% in October. Less marked findings for 10-day data.
Hicks [21] (1983)	USA	1976-1978	Sleep	✓	X	All collisions.	1 week before & 1 week after.	Spring & Autumn: Regardless of season, DST change was associated with a significant increase in RTCs during the post-change weeks.
Hicks [22] (1998)	USA	1989-1992	Sleep	✓ ¹	X	All alcohol-related fatal road	1 week before & 1 week after.	Spring & Autumn: Alcohol-related fatalities increased significantly in the first week after

¹ Spring and autumn transition data were combined as not statistically different from one another

						traffic collisions.		the DST transition, although this returned to baseline by the second week. Note: Spring and autumn combined as not statistically significantly different.
Huang [23] (2010)	USA	2001-2007	Sleep and light	✓	✓	All collisions & fatal collisions.	First day (Sunday) of time change compared with other Sundays.	Spring: Short-term effect is not statistically significant. Autumn: Short-term effect is not statistically significant.
Lahti [24] (2010)	Finland	1981 - 2006	Sleep	✓	X	All collisions.	1 week before & 1 week after.	Spring & Autumn: Transitions into and out of DST did not significantly increase the amount of traffic collisions.
Lambe [25] (2000)	Sweden	1984 - 1995	Sleep	✓	X	All collisions.	Monday before & after, & one week after.	Spring & Autumn: The shift to and from DST did not have measurable effects on RTC incidence.
Meyerhoff [26] (1978)	USA	1973-1974	Light	✓	✓	All fatal collisions.	Morning and evening on day of transitions in 1974 (DST) and 1973 (No DST).	Spring & Autumn: DST reduced fatal RTCs by approximately 1% during several weeks at spring and autumn transitions. This effect was attributed to the spring transition, with little change during the autumn transition.
Sarma & Carey [27] (2016)	Republic of Ireland	2003-2012	Light	✓	✓ Morning, Evening, Combined Morning and Evening, full day.	Collisions, injuries, fatalities for different road users (pedestrians, cyclists and all road users).	1 and 2 weeks before and after transition into and out of DST.	Spring: No change in collisions. Increase in casualties in the mornings in 2-week comparisons (33.5%) and increase in pedestrian casualties (105.3%). Autumn: Decrease in collisions in the morning period at 1 (26.9% decrease) and 2 (17.3% decrease) week comparisons. Evening pedestrian casualties increased in both sets of analyses (68% higher at 1 week and 32.5% over two weeks).
Smith [28] (2014)	USA	2002-2011	Sleep and light	✓	✓	All fatal collisions.	Unclear.	Spring: 5.4-7% increase in fatal RTCs immediately following spring transition. Autumn: No impact in autumn.
Sood & Ghosh [29] (2007)	USA	1976-2003	Sleep and light	Spring only	X	Fatal collisions: Pedestrians and motor vehicle occupants.	Monday before, Monday of, and Monday after.	Spring: No short-term effect, having controlled for collision trends within and across years.
Stevens [30] (2006)	USA	1998-2000	Light	✓	✓	Fatal & nonfatal collisions	5 working days before & after.	Spring & Autumn: The immediate impact of DST, both spring and autumn, is negative,

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49

						involving pedestrians and motor vehicle occupants.		but is particularly marked for the autumn transition. An increase in daylight results in a decrease in the number of pedestrian crashes.
Varughese [31] (2001)	USA	1975-1995	Sleep	✓	X	All fatal collisions.	Saturday/Sunday and Monday of the transition vs. same days for the week before and after.	Spring: There was a small significant increase in fatal RTCs on Monday from 78.2 to 83.5 (no impact on Saturday or Sunday). Autumn: There was a significant increase was found in fatalities for Sunday from 126.4 to 139.5 (no difference for Saturday or Monday).
Whittaker [32] (1996)	UK	1983-1993	Light	✓	✓	Casualties: vehicle occupants, cyclists, pedestrians, children.	1 week before & 1 week after.	Overall net reduction in casualty numbers for BST periods compared to GMT. Spring: Onset of BST in spring associated with reductions in casualty numbers of 6% in morning & 11% in evening. No rise in casualties with the darker mornings. Reductions were maximal in the pedestrian (36%), cyclist (11%), and schoolchild (24%) subgroups. Autumn: The change back to GMT in autumn produced an anticipated reduction (6%) in casualties in the lighter mornings. Darker evenings associated with significant increases in casualties (4%), mainly vehicle (5%) and pedestrian (8%).

Table 2: Characteristics of papers included: Long-term timeframe

Author (Year)	Country	Years	Focus (sleep/light)	By season	By time of day (morning/evening)	Population/ Outcome	Timeframe	Finding (narrative)
Chu [33] (1976)	USA	1974	Light	Jan-March only	✓	All fatalities.	3 months.	Overall estimate of 47 fatalities saved (8%) in the first half of 1974 that can be attributed to DST. A sharply higher fatality rate during morning rush hour and a sharply lower rate in the afternoon peak hour.
Coate [34] (2004)	USA	1998 and 1999	Light	✓	✓	Fatalities: Pedestrians & motor vehicle occupants.	1 month before & 1 month after.	Full year DST would reduce pedestrian fatalities by 171 per year (13%), and motor vehicle occupant fatalities by 195 per year (3%). An hour later sunset would reduce evening pedestrian fatalities by about one-quarter and an hour later sunrise would increase morning fatalities by about one-third. No increased risk to school children from full year DST.
Crawley [19] (2012)	USA	1976-2010	Both sleep and light	✓	X	All collisions.	13 weeks before & 9 weeks after. Also comparison of 1987-2003 to 1976-1986.	Significant fatal crash-saving effects of DST in the long run, shown particularly in the autumn test. 'The spring test gave little evidence either way'.
Ferguson [9] (1995)	USA	1987 - 1991	Light	✓	✓	Fatal collisions: Pedestrians & motor vehicle occupants.	13 weeks before & 9 weeks after.	The most notable effects of changing light levels on fatal crashes were seen when light levels changed from light to twilight (collisions increased) and when twilight changed to light (collisions decreased). Benefits are smallest during the darkest winter months because the evening reduction is increasingly offset by increases

								during the morning. An estimated 901 fewer fatal crashes (727 involving pedestrians and 174 involving vehicle occupants) might have occurred had DST been retained year-round from 1987-1991.
Huang [23] (2010)	USA	2001-2007	Both sleep and light	✓	✓	All collisions and fatal collisions.	8 weeks before & after.	DST, all else equal, is associated with fewer RTCs and fatal RTCs for most day parts (except 9am-3pm).
Meyerhoff [26] (1978)	USA	1973-1974	Light	✓	✓	All fatal collisions.	Jan-Feb and March-April 1974 (DST) and Jan-Feb and March-April 1973 (No DST) (long-term).	A net reduction of about 0.7% during the DST period, March and April 1974, compared to the non-DST period. March and April 1973, but little net DST effect on fatal accidents in winter. A marked decrease in evening fatalities is observed, but the morning increase is not seen as anticipated.
Sarma & Carey [27] (2016)	Republic of Ireland		Light	✓	✓	Collisions, injuries, fatalities for different road users (pedestrians, cyclists and all road users).	5 and 7 weeks pre and post transition into and out of DST.	Transition into DST: Increase in collisions in evening period for 5 week (12.6%) and 7 week (13.1%) analyses. Also increase in casualties in evening period at 5 week (17.6% increase) and 7 weeks (19.5% increase). Overall (combining morning and evening peak periods) increase in casualties at 5 week (10.5% increase) and 7-week (12.7%) analyses. Transition out of DST: Increase in morning casualties at 7 weeks (12.4% increase) and overall increase in casualties when morning and evening combined for 7 weeks (5.5% increase).
Sood & Ghosh [29] (2007)	USA	1976-2003	Sleep and light	Spring only	X	Fatal collisions: Pedestrians and motor vehicle occupants.	13 weeks before & 8 weeks after.	Long-term reduction of 8-11% in RTCs involving pedestrians, and 6-10% in RTCs involving vehicle occupants.
Sullivan [35] (2001)	USA	1987-1997	Light	✓	Evening only	Fatal collisions: Pedestrians and	3 weeks before and after.	Pedestrian fatalities 4.14 times more likely in darkness (DST) than in daylight (ST).

						motor vehicles.		Interaction between light and alcohol use.
Sullivan [36] (2002)	USA	1987-1997	Light	✓	✓	Fatal collisions: Pedestrians and motor vehicle occupants.	9 weeks before and after.	Overall, pedestrian fatalities 3 to 6.75 times more likely in darkness (ST) than in daylight (DST), while other crashes were only marginally more likely in darkness Spring am: Twilight shows a decline in crashes from week-8 (39 crashes) to week-1 (8 crashes); at the changeover, when the period is returned to darkness, the crash level rises again Spring pm: the crash frequency is high during the dark period just before the DST changeover, and drops to 54, the week after the changeover and declines more the following week to 32 Autumn am: 79 crashes before the transition and 29 after Autumn pm: In the week before the transition there were 65 crashes, in the following week there were 227, an increase of three and a half times.
Sullivan [37] (2003 & 2004)	USA	1987-2001	Light	Autumn only	Evening only	Fatal collisions: Motor vehicle occupants only.	5 weeks before & after.	Rear-end collisions change from an average count of about 13 crashes in the light (DST) to an average of 37 in the dark (ST). Impact of light on crash risk varies across rear-end collision types.
Sullivan [6] (2007)	USA	FARS= 1987-2004; NCDO T=1991-1999.	Light	✓	Evening only	Fatal & nonfatal collisions: Pedestrian (child, adult, elderly) and motor vehicle occupants.	5 weeks before and after.	Fatal crashes involving pedestrians, animals, and other motor vehicles showed the most reliable increases in risk in low light levels (ST). Children show a reliably greater risk in darkness, but this risk is much smaller than the risk observed for adult and elderly pedestrians – which is nearly 7 times greater in darkness. Even when the data are not separated by age, the apparent increase in pedestrian risk in the dark is very strong.

1
2
3 Data for 17 studies (71%) were from the United States (US), with 8% (n=2) of studies
4 based on DST in the UK. Other countries included were Canada, Finland, Israel, Republic of
5 Ireland and Sweden (21% of studies). Years captured in the analyses ranged from 1973 to
6
7 2012.

8
9
10 Seventeen of the included studies (71%) investigated the short-term effects of DST by
11 examining the period immediately (two weeks or less) before and after the DST shift. Of these
12 papers, eight (47%) focused on the effects of sleep disruptions caused by the DST shift (see
13 next section for more detail), five (29%) focused on light levels and four (24%) looked at both
14 sleep and light (see Table 1). Twelve of the studies (50%) examined the overall or long-term
15 effects of DST, focusing on changes in light levels that result from DST. Timeframes captured
16 in these studies ranged from 3 to 13 weeks around the DST transitions (see Table 2). Five
17 studies examined both short- and long-term effects, and these analyses were treated separately
18 in the synthesis.
19
20
21
22
23
24
25
26
27
28
29
30

31 Six of the short-term analyses (35%) of the short-term analyses distinguished between
32 morning and evening risk, while seven (58%) of the long-term analyses did so. Almost all
33 (94%, n=16) of the short-term analyses separated spring from autumn DST transitions, while
34 75% (n=9) of the long-term studies made this distinction. Nine of the 24 studies (38%)
35 provided analyses by road user (e.g. pedestrian vs. motor vehicle user).
36
37
38
39
40
41
42

43 **What is the impact of DST on road traffic collisions, injuries and fatalities?**

44 *Short-term impact*

45
46
47 For the transition into DST (i.e. the spring shift) findings relating to the spring DST
48 shift were inconsistent across studies. Sixteen of the short-term studies provided relevant
49 statistical data. Three of these studies (19%) reported a reduction in collisions, six (38%)
50 reported an increase in collisions and seven (44%) reported no change. Increases were largely
51 attributed to sleep disruption (latency and duration), in line with previous research [12 13].
52
53
54
55
56
57
58
59
60

1
2
3 An examination of the short-term change in road traffic collisions around the transition
4 back to standard time (ST) in autumn may offer a purer test of the impact of DST on road
5 safety. This transition results in improved lighting in the morning, but a reduction in the
6 evening, which should lead to an increase in road traffic collisions. Since this transition does
7 not lead to a 'missing hour', sleep effects should be less pronounced. Fifteen of the short-term
8 studies provided relevant data. Findings were inconsistent across studies, with five studies
9 (33%) reporting a decrease in collisions, five studies reporting an increase, and five studies
10 reporting no change.
11
12
13
14
15
16
17
18
19

20
21 It is worth noting that a majority of these short-term studies focused on the effects of
22 sleep deprivation on road traffic collisions, particularly during the spring transition, rather
23 than considering the potential impact of a permanent shift in time zones on road safety
24 outcomes.
25
26
27
28

29 *Long-term impact*

30
31
32 Twelve of the 24 studies examined the longer-term impact (>2 weeks) of DST on road
33 safety outcomes. These studies reported a reduction in collisions, injuries and fatalities
34 associated with DST. The exception was the analyses of trends in the Republic of Ireland,
35 which reported increases in collisions and casualties in some of the analyses. For those that
36 did report reductions, the overall magnitude of this effect, though hard to estimate given the
37 variability in study approaches and analyses, tended to be small. Huang and Levinson, for
38 example, report that 'a day in DST, all else equal, is associated with about 0.09% fewer
39 crashes than a day in ST [standard time]' [23, p.519]. Meyerhoff reported a net reduction of
40 0.7% of fatal collisions during 2 months in DST, compared to 2 months in ST, and little
41 overall impact of DST in winter months [26].
42
43
44
45
46
47
48
49
50
51
52

53
54 Importantly, there was an observed increase in collisions during the morning hours in
55 DST (although not in all studies; see [26]), but it was noted that the overall benefit to road
56
57
58
59
60

1
2
3 safety tended to outweigh the morning risks. Several studies extrapolated from the findings of
4
5 their analyses to the impact of retaining DST year-round.
6

7
8 **What is the impact of DST on road traffic collisions, injuries and fatalities for different**
9
10 **types of road users (e.g. vehicle occupants Vs pedestrians, cyclists, etc.)?**

11
12 Of the nine studies that analysed DST effects on different types of road users, the
13
14 beneficial effects of DST were most pronounced for pedestrians and cyclists. In one study, the
15
16 estimated effects of retaining DST approximated 13% fewer pedestrian fatalities, and 3%
17
18 fewer vehicle occupant fatalities [34]. The collision risk posed to pedestrians following the
19
20 transition back to ST was found to be greater than that for motor vehicle occupants. Ferguson
21
22 *et al*, for example, reported a greater collision risk for pedestrians than for motor vehicle
23
24 occupants, following the transition from DST to ST. Specifically, they found the change from
25
26 daylight to twilight to be associated with a 300% increase in fatal collisions involving
27
28 pedestrians. Of the 901 fewer fatal collisions they estimate would have occurred from 1987 to
29
30 1991, had DST operated year-round, 727 of these would have involved pedestrians, while 174
31
32 would have involved motor vehicle occupants [9]. Whittaker [32] reported that the onset of
33
34 DST in spring was associated with a reduction in casualties that was particularly pronounced
35
36 for pedestrians (36%) and cyclists (11%). Sarma & Carey [27] found a significant reduction in
37
38 cyclist casualties following the autumn transition, though the authors noted that the darker
39
40 evenings may have led to reductions in bicycle use, which would have impacted on total
41
42 incidence.
43
44
45
46

47
48 Sullivan and Flannagan found 4.1 times as many pedestrian fatalities in darkness
49
50 (during ST) compared to daylight (during DST), and 1.3 times as many motor vehicle
51
52 collisions in darkness, compared to daylight. Thus, although darkness increased collision risk
53
54 for both groups of road users, the risks posed were greatest for pedestrians [35]. Sood and
55
56 Ghosh reported an overall long-term reduction in collisions involving both pedestrians (8 to
57
58
59
60

1
2
3 11%) and motor vehicle occupants (6 to 10%). They noted that the 'saving' in collisions
4
5 peaked in the third (for pedestrians) and fourth (for motor vehicle occupants) weeks after DST
6
7 onset [29].
8

9
10 Again, however, it is important to note that the impact of DST on pedestrian risk may
11
12 differ from morning to evening. Coate and Markowitz estimated that year-round DST would
13
14 reduce pedestrian fatalities in the evening by one-quarter, but increase those in the morning by
15
16 one-third. They conclude that, since pedestrian activity is higher in the evening compared to
17
18 the morning, year-round DST would reduce overall pedestrian fatalities by 13% [34].
19

20 21 **Quality Assessment**

22
23 Table 3 summarises our assessment of the value the studies included in the review
24
25 provided, based on the extent to which each can inform the core review questions. With the
26
27 exception of one paper, all studies had access to data gathered through some form of
28
29 mandatory reporting system (e.g. national road safety database). Ideally, papers would report
30
31 analyses for the spring and autumn transitions, and capture both short- and long-term impact
32
33 of DST, for morning and evening periods. It was typical for most of the papers to report
34
35 separate analyses for spring and autumn (21 papers).
36
37

38
39 However, just 5 papers included both short- and long-term analyses, and less than half
40
41 (12 papers) reported results for morning and evening periods. Similarly, most of the papers
42
43 (15 papers) did not report data for different road users (e.g pedestrian and vehicle occupants)
44
45 and did not consider other contributory factors for collision risk (15 papers), which would
46
47 have facilitated the synthesis reported here. While most of the papers included incidence or
48
49 mean/standard deviation descriptive results (19 papers), there was considerable heterogeneity
50
51 across studies in terms of the time periods around the DST transitions selected for the analyses
52
53 (see Tables 1 and 2 for details); this rendered the data as a whole difficult to subject to meta-
54
55 analysis.
56
57
58
59
60

Table 3: Summary results of quality assessment

Author (year)	Data Source	Sampling				Statistical Reporting		Focus
		Official ¹	Short & Long Term ²	Morning & Evening ³	Spring & Autumn ⁴	Multiple Road Users ⁵	Incidence/ Mean/SD ⁶	Other Factors ⁷
Askenasy (1997)	Y	N	N	Y	N	Y	N	N
Chu (1976)	Y	N	Y	N	N	Y	Y	Y
Coate (2004)	Y	N	Y	Y	Y	Y	Y	Y
Conte (2007)	Y	N	N	Y	N	Y	Y	N
Coren (1996)	Y	N	N	Y	N	Y	N	N
Crawley (2012)	Y	Y	N	Y	N	N	N	Y
Ferguson (1995)	Y	N	Y	Y	Y	N	N	Y
Green (1980)	Y	N	N	Y	N	Y	N	Y
Hicks (1998)	Y	N	N	Y	N	Y	Y	N
Hicks (1983)	Y	N	N	Y	N	Y	N	N
Huang (2010)	Y	Y	Y	Y	N	N	Y	Y
Lahti (2010)	Y	N	N	Y	N	N	Y	N
Lambe (2000)	Y	N	N	Y	N	Y	N	N
Meyerhoff (1978)	Y	Y	Y	Y	N	Y	N	Y
Sarma & Carey (2015)	Y	Y	Y	Y	Y	Y	Y	Y
Smith (2014)	Y	N	Y	Y	N	N	Y	Y
Sood and Ghosh (2007)	Y	Y	N	N	Y	Y	N	Y
Stevens (2005)	?	N	Y	Y	Y	Y	N	Y
Sullivan (2001)	Y	N	Y	Y	Y	Y	Y	Y
Sullivan (2002)	Y	N	Y	Y	Y	Y	N	Y
Sullivan (2003&2004)	Y	N	N	N	Y	Y	N	Y
Sullivan (2007)	Y	N	Y	Y	N	Y	N	Y
Varughese (2001)	Y	N	N	Y	N	Y	N	N
Whitaker (1996)	Y	N	Y	Y	Y	Y	N	Y

1. Data derived from official collision data source such as police or national authority. 2. Short term and long term analyses reported. 3. Separate analyses for morning and evening collisions is more sensitive to DST effects. 4. Separate analyses for Spring and Autumn transitions can test hypothesized DST effects for each transition. 5. Separate analyses for different road users is important to the CET debate. 6. Reporting of incidence and Mean/SD would support a meta-analytic review if comparison periods were uniform across studies. 7. Reporting data for factors that could explain, in whole or part, collision trends around DST transitions aids interpretation of light effects. 8. Papers that focused specifically on light transitions, rather than only on the impact of time changes on sleep duration and latency, were more relevant to our review (if they focused on both sleep and light, they were coded Y).

DISCUSSION

Summary findings

The core objective of this review has been to contribute to the evidence base that can inform the current debate on the potential road safety benefit of a time-zone change that would result in brighter evenings. The most valid evidence from the DST literature is that pertaining to the *short-term* impact of shifting to, and from, DST. These analyses should allow us to isolate the 'light' effect, given that there should be minimal changes in extraneous factors. Findings from these studies were inconsistent, with results suggesting that shifting light by adjusting time can have positive or negative road safety consequences, or result in no change. In addition, most studies did not extrapolate findings to hypothetical conditions under a more permanent change in time. Thus, the short-term evidence cannot support or refute the assertion that a move to CET will have a road safety benefit in the UK and RoI.

The long-term findings were more consistent, and the overall impact of DST was positive (i.e. risk-reducing) in a majority of studies included. The difficulty here, however, is two-fold. First, this reduction cannot be attributed solely to DST, as a variety of risk factors for road collisions vary in the long-term, including traffic flow and weather conditions. Second, with the exception of the analyses from Ireland, all studies were conducted in the USA, undermining the predictive validity of the findings when applied to other jurisdictions. In summary, the review reports inconsistent findings for the short-term impact of DST, and questions the validity of the longer-term analyses.

Limitations

There were a number of limitations associated with this review. First, the DST literature reviewed does not provide a test of the impact of a permanent time-zone shift on road safety. DST, which involves a temporary shift of light between morning and evening, is distinct from a time-zone change, which would involve a permanent shift of one hour, and

1
2
3 then an additional one-hour shift during DST. However, in the absence of road safety data
4
5 from jurisdictions that have gone through a permanent time-zone shift, the DST literature is an
6
7 important and relevant source of evidence that is often referenced in these debates.
8

9
10 Second, the review excluded a small number of papers that examined collisions before,
11
12 during and after the British Standard Time experiment that occurred between 1968 and 1971.
13
14 Apart from not meeting our inclusion criteria (i.e. they did not examine DST), these papers,
15
16 we would argue, lack validity in terms of contemporary road safety policy-making given the
17
18 dramatic changes in traffic volume, road infrastructure, vehicle engineering and driver
19
20 behaviour that have occurred over the last 40 years. We acknowledge, however, that others
21
22 who *have* considered the road safety evidence from the British Standard Time experiment
23
24 have estimated that a permanent move to CET would have potential savings for pedestrians
25
26 and vehicle occupants (as reported in the introduction to this paper).
27
28

29
30 Third, the review is limited by the heterogeneous nature of the literature base. This
31
32 includes variation in time sampling, statistical analyses, and populations of interest. One
33
34 consequence of this heterogeneity is that we were unable to complete a meta-analysis of the
35
36 studies. For example, the papers report findings based on differing time periods before and
37
38 after DST (e.g. timeframes among short-term studies varied from one day to two weeks
39
40 around the transitions). It is very difficult to reconcile this heterogeneity of comparisons into
41
42 meaningful mean or dispersion effects during meta-analysis (for more see [38]) and [39]).
43
44

45
46 The review is also limited by the methodological and statistical limitations of the
47
48 individual studies. In particular, individual studies tended not to attempt to isolate light effects
49
50 by statistically controlling for other potential explanatory variables, such as traffic volume, for
51
52 example, or holiday periods. The absence of reporting of the incidence rates behind the
53
54 analyses in the papers is a further limitation, though it is worth noting that the long-term
55
56 analyses were characterised by large datasets of collisions and samples only became small
57
58
59
60

1
2
3 where analyses involved sub-sets of data for short-term effects and involving specific types of
4 collisions (e.g. in Hicks [22] review of alcohol related fatalities the incidence fell below 50
5 fatalities when examining fatalities across time periods during the day).
6
7
8

9
10 Finally, the research team decided to double screen 15% of papers when isolating
11 papers that met our inclusion/exclusion criteria, rather than double-screening all papers. The
12 original review protocol proposed that double screening would continue up until high inter-
13 coder reliability was reached; in practice, this was achieved after 15% of papers were
14 screened.
15
16
17
18
19

20 **Conclusions and Implications**

21
22 In summary, the picture emerging from this review is complex. We found that the
23 short-term effects of DST are likely to be small and potentially negative or positive depending
24 on time of year and day. The long-term effects tend to be positive, but may be attributable to
25 factors other than light. Future research needs to take into consideration these factors where
26 possible.
27
28
29
30
31
32

33
34 The DST literature, taken as a body of research, should not be used to support or refute
35 the assertion that shifts in time-zones can have a road safety benefit. Inconsistent findings and
36 conclusions across studies, combined with the heterogeneous nature of the studies, mean that
37 DST could possibly have a positive or negative impact on collisions, but may also have no
38 effect. For the UK and Republic of Ireland, where a move to CET is being debated, arguments
39 may be on a stronger foundation where they focus on the economic value (or not) of such a
40 change rather than the potential impact on road safety.
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

Author Contribution Statement

KS conceived the systematic review and supervised the research. RC was primarily responsible for database searching and reviewing texts for inclusion. KS and RC both contributed to the data extraction, data analysis, and manuscript drafting.

Funding

This paper is based on a report commissioned by the Road Safety Authority of Ireland. The views reported here are those of the authors and do not necessarily represent the views of the Road Safety Authority.

Data Sharing Statement

The datasets supporting the conclusions of this article are available on request from the corresponding author.

Licence to BMJ Publishing Group Limited

I Kiran M. Sarma The Corresponding Author of this article contained within the original manuscript which includes any diagrams & photographs within and any related or stand alone film submitted (the Contribution”) has the right to grant on behalf of all authors and does grant on behalf of all authors, a licence to the BMJ Publishing Group Ltd and its licencees, to permit this Contribution (if accepted) to be published in the BMJ and any other BMJ Group products and to exploit all subsidiary rights, as set out in our licence set out at:

<http://www.bmj.com/about-bmj/resources-authors/forms-policies-and-checklists/copyright-open-access-and-permission-reuse>. I am one author signing on behalf of all co-owners of the Contribution.

References

1. Schiavenza M. China Only Has One Time Zone—and That's a Problem. Secondary China Only Has One Time Zone—and That's a Problem 2013. <http://www.theatlantic.com/china/archive/2013/11/china-only-has-one-time-zone-and-thats-a-problem/281136/>.
2. BBC. Russian clocks go back for last time. Secondary Russian clocks go back for last time 2014. <http://www.bbc.co.uk/news/world-europe-29773559>.
3. BBC. North Korea's new time zone to break from 'imperialism'. Secondary North Korea's new time zone to break from 'imperialism' 2015. <http://www.bbc.co.uk/news/world-asia-33815049>.
4. Tadeo M. Breaking With Old Politics May Begin With Clock Change in Spain. Secondary Breaking With Old Politics May Begin With Clock Change in Spain 2016. <http://www.bloomberg.com/news/articles/2016-02-25/breaking-with-old-politics-may-begin-with-clock-change-in-spain>.
5. ROSPA. Single Double British Summertime Factsheet 2014.
6. Sullivan JM, Flannagan MJ. Determining the potential safety benefit of improved lighting in three pedestrian crash scenarios. *Accident Analysis and Prevention* 2007;**39**(3):638-47 doi: 10.1016/j.aap.2006.10.010[published Online First: Epub Date].*
7. Broughton J, Stone M. *A new assessment of the likely effects on road accidents of adopting SDST*: Transport Research Laboratory, 1998.
8. Adams J, White M, Heywood P. Year-round daylight saving and serious or fatal road traffic injuries in children in the north-east of England. *Journal of Public Health* 2005;**27**(4):316-17 doi: 10.1093/pubmed/fdi047[published Online First: Epub Date].
9. Ferguson SA, Preusser DF, Lund AK, et al. Daylight Saving Time and Motor Vehicle Crashes: The Reduction in Pedestrian and Vehicle Occupant Fatalities. *American Journal of Public Health* 1995;**85**(1):92-95 *
10. Plainis S, Murray IJ, Pallikaris IG. Road traffic casualties: understanding the night-time death toll. *Injury Prevention* 2006;**12**(2):125-28 doi: 10.1136/ip.2005.011056[published Online First: Epub Date].
11. Harrison Y. The impact of daylight saving time on sleep and related behaviours. *Sleep Medicine Reviews* 2013;**17**(4):285-92 doi: 10.1016/j.smrv.2012.10.001[published Online First: Epub Date].
12. Lahti TA, Leppämäki S, Lönnqvist J, et al. Transitions into and out of daylight saving time compromise sleep and the rest-activity cycles. *BMC physiology* 2008;**8**(1):1
13. Kantermann T, Juda M, Meroow M, et al. The human circadian clock's seasonal adjustment is disrupted by daylight saving time. *Current Biology* 2007;**17**(22):1996-2000 doi: 10.1016/j.cub.2007.10.025[published Online First: Epub Date].
14. Popay J, Roberts H, Sowden A, et al. Guidance on the conduct of narrative synthesis in systematic reviews. *ESRC methods programme* 2006;**15**(1):047-71
15. Downs S, Black N. The feasibility of creating a checklist for the assessment of the methodological quality both of randomised and non-randomised studies of health care interventions. *J Epidemiol Community Health* 1998;**52**:377-84
16. Askenasy JJ, Goldstein R, Askenasy N, et al. Some light on the controversy about the effects of the shift to daylight saving time on road accidents. In: MeierEwert K, Okawa M, eds. *Sleep-Wake Disorders*, 1997:67-72.*
17. Conte MN, Steigerwald DG. Do Daylight-Saving Time Adjustments Impact Human Performance? 2007 *
18. Coren S. Daylight savings time and traffic accidents. *New England Journal of Medicine* 1996;**334**(14):924-25 *

19. Crawley J. Testing for Robustness in the Relationship between Fatal Automobile Crashes and Daylight Saving Time. 2012 *
20. Green H. Some effects on accidents of changes in light conditions at the beginning and end of British summer time, 1980.*
21. Hicks RA, Lindseth K, Hawkins J. Daylight saving-time changes increase traffic accidents. *Perceptual & Motor Skills* 1983;**56**:64-66 *
22. Hicks GJ, W. Davis J, Hicks RA. Fatal alcohol-related traffic crashes increase subsequent to changes to and from daylight savings time. *Perceptual and motor skills* 1998;**86**(3):879-82 *
23. Huang A, Levinson D. The effects of daylight saving time on vehicle crashes in Minnesota. *Journal of Safety Research* 2010;**41**(6):513-20 doi: 10.1016/j.jsr.2010.10.006[published Online First: Epub Date].*
24. Lahti T, Nysten E, Haukka J, et al. Daylight saving time transitions and road traffic accidents. *Journal Of Environmental And Public Health* 2010;**2010**:657167-67 doi: 10.1155/2010/657167[published Online First: Epub Date].*
25. Lambe M, Cummings P. The shift to and from daylight savings time and motor vehicle crashes. *Accident Analysis and Prevention* 2000;**32**(4):609-11 doi: 10.1016/s0001-4575(99)00088-3[published Online First: Epub Date].*
26. Meyerhoff NJ. The influence of daylight saving time on motor vehicle fatal traffic accidents. *Accident Analysis and Prevention* 1978;**10**(3):207-21 *
27. Sarma K, Carey R. The potential impact of the implementation of the Brighter Evenings Bill on road safety in the Republic of Ireland. A report for the Road Safety Authority of Ireland 2015 *
28. Smith AC. Spring Forward at Your Own Risk: Daylight Saving Time and Fatal Vehicle Crashes. 2014 *
29. Sood N, Ghosh A. The short and long run effects of daylight saving time on fatal automobile crashes. *The BE Journal of Economic Analysis & Policy* 2007;**7**(1)*
30. Stevens CR, Lord D. Evaluating safety effects of daylight savings time on fatal and nonfatal injury crashes in texas. *Transportation Research Record: Journal of the Transportation Research Board* 2006;**1953**(1):147-55 *
31. Varughese J, Allen RP. Fatal accidents following changes in daylight savings time: the American experience. *Sleep Medicine* 2001;**2**(1):31-36 doi: 10.1016/s1389-9457(00)00032-0[published Online First: Epub Date].*
32. Whittaker J. An investigation into the effects of British Summer Time on road traffic accident casualties in Cheshire. *Journal of accident & emergency medicine* 1996;**13**(3):189-92 *
33. Chu BY-C, Nunn GE. An analysis of the decline in California traffic fatalities during the energy crisis. *Accident Analysis & Prevention* 1976;**8**(3):145-50 *
34. Coate D, Markowitz S. The effects of daylight and daylight saving time on US pedestrian fatalities and motor vehicle occupant fatalities. *Accident Analysis and Prevention* 2004;**36**(3):351-57 doi: 10.1016/s0001-4575(03)00015-0[published Online First: Epub Date].*
35. Sullivan JM, Flannagan M. Characteristics of pedestrian risk in darkness. 2001 *
36. Sullivan JM, Flannagan MJ. The role of ambient light level in fatal crashes: Inferences from daylight saving time transitions. *Accident Analysis and Prevention* 2002;**34**(4):487-98 *
37. Sullivan JM. Visibility and rear-end collisions involving light vehicles and trucks. 2004 *
38. Higgins J, Green S. *Cochrane Handbook for Systematic Reviews of Interventions* The Cochrane Collaboration, 2011, 2011.

- 1
2
3 39. Borenstein M, Hedges L, Higgins J, et al. *Introduction to Meta-Analysis*: John Wiley &
4 Sons, LTD, 2009.
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

For peer review only

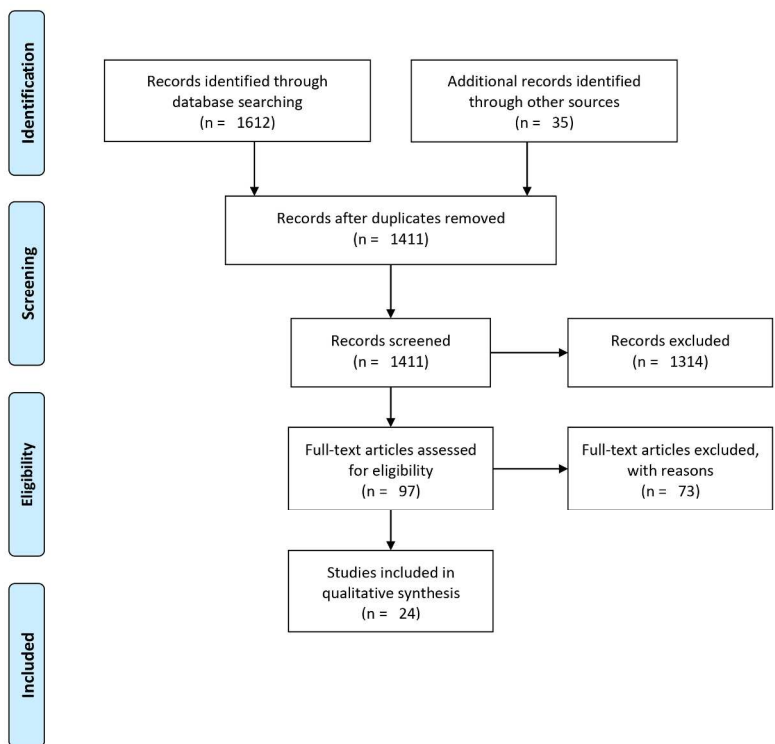
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

Figure Legends

Figure 1: PRISMA flow-chart outlining selection of studies

For peer review only

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60



From: Moher D, Liberati A, Tetzlaff J, Altman DG, The PRISMA Group (2009). Preferred Reporting Items for Systematic Reviews and Meta-Analyses: The PRISMA Statement. PLoS Med 6(7): e1000097. doi:10.1371/journal.pmed1000097

For more information, visit www.prisma-statement.org.

Figure 1: PRISMA flow-chart outlining selection of studies
Figure 1
215x279mm (300 x 300 DPI)

1
2
3
4 **Full Search Strategy for Ovid**
5

- 6 1. daylight saving.mp
- 7 2. dst.mp
- 8 3. time change.mp.
- 9 4. road safety.mp.
- 10 5. road traffic.mp.
- 11 6. collision.mp.
- 12 7. crash.mp.
- 13 8. accident.mp.
- 14 9. 1 or 2 or 3
- 15 10. 4 or 5 or 6 or 7 or 8
- 16 **11. 9 and 10**
- 17
- 18
- 19
- 20
- 21
- 22
- 23
- 24
- 25
- 26
- 27
- 28
- 29
- 30
- 31
- 32
- 33
- 34
- 35
- 36
- 37
- 38
- 39
- 40
- 41
- 42
- 43
- 44
- 45
- 46
- 47
- 48
- 49
- 50
- 51
- 52
- 53
- 54
- 55
- 56
- 57
- 58
- 59
- 60



PRISMA 2009 Checklist

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49

Section/topic	#	Checklist item	Reported on page #
TITLE			
Title	1	Identify the report as a systematic review, meta-analysis, or both.	1
ABSTRACT			
Structured summary	2	Provide a structured summary including, as applicable: background; objectives; data sources; study eligibility criteria, participants, and interventions; study appraisal and synthesis methods; results; limitations; conclusions and implications of key findings; systematic review registration number.	2
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of what is already known.	6
Objectives	4	Provide an explicit statement of questions being addressed with reference to participants, interventions, comparisons, outcomes, and study design (PICOS).	6-7
METHODS			
Protocol and registration	5	Indicate if a review protocol exists, if and where it can be accessed (e.g., Web address), and, if available, provide registration information including registration number.	N/A
Eligibility criteria	6	Specify study characteristics (e.g., PICOS, length of follow-up) and report characteristics (e.g., years considered, language, publication status) used as criteria for eligibility, giving rationale.	6
Information sources	7	Describe all information sources (e.g., databases with dates of coverage, contact with study authors to identify additional studies) in the search and date last searched.	7
Search	8	Present full electronic search strategy for at least one database, including any limits used, such that it could be repeated.	Supplementary File 1
Study selection	9	State the process for selecting studies (i.e., screening, eligibility, included in systematic review, and, if applicable, included in the meta-analysis).	7
Data collection process	10	Describe method of data extraction from reports (e.g., piloted forms, independently, in duplicate) and any processes for obtaining and confirming data from investigators.	8
Data items	11	List and define all variables for which data were sought (e.g., PICOS, funding sources) and any assumptions and simplifications made.	8
Risk of bias in individual studies	12	Describe methods used for assessing risk of bias of individual studies (including specification of whether this was done at the study or outcome level), and how this information is to be used in any data synthesis.	Quality assessment Page 9
Summary measures	13	State the principal summary measures (e.g., risk ratio, difference in means).	N/A



PRISMA 2009 Checklist

Page 1 of 2

Synthesis of results	14	Describe the methods of handling data and combining results of studies, if done, including measures of consistency (e.g., I^2) for each meta-analysis.	9
----------------------	----	---	---

Section/topic	#	Checklist item	Reported on page #
Risk of bias across studies	15	Specify any assessment of risk of bias that may affect the cumulative evidence (e.g., publication bias, selective reporting within studies).	N/A
Additional analyses	16	Describe methods of additional analyses (e.g., sensitivity or subgroup analyses, meta-regression), if done, indicating which were pre-specified.	N/A
RESULTS			
Study selection	17	Give numbers of studies screened, assessed for eligibility, and included in the review, with reasons for exclusions at each stage, ideally with a flow diagram.	10
Study characteristics	18	For each study, present characteristics for which data were extracted (e.g., study size, PICOS, follow-up period) and provide the citations.	11-20
Risk of bias within studies	19	Present data on risk of bias of each study and, if available, any outcome level assessment (see item 12).	Quality assessment Page 24
Results of individual studies	20	For all outcomes considered (benefits or harms), present, for each study: (a) simple summary data for each intervention group (b) effect estimates and confidence intervals, ideally with a forest plot.	N/A
Synthesis of results	21	Present results of each meta-analysis done, including confidence intervals and measures of consistency.	N/A
Risk of bias across studies	22	Present results of any assessment of risk of bias across studies (see Item 15).	N/A
Additional analysis	23	Give results of additional analyses, if done (e.g., sensitivity or subgroup analyses, meta-regression [see Item 16]).	N/A
DISCUSSION			
Summary of evidence	24	Summarize the main findings including the strength of evidence for each main outcome; consider their relevance to key groups (e.g., healthcare providers, users, and policy makers).	26
Limitations	25	Discuss limitations at study and outcome level (e.g., risk of bias), and at review-level (e.g., incomplete retrieval of identified research, reporting bias).	26-28
Conclusions	26	Provide a general interpretation of the results in the context of other evidence, and implications for future research.	28
FUNDING			
Funding	27	Describe sources of funding for the systematic review and other support (e.g., supply of data); role of funders for the systematic review.	29



PRISMA 2009 Checklist

From: Moher D, Liberati A, Tetzlaff J, Altman DG, The PRISMA Group (2009). Preferred Reporting Items for Systematic Reviews and Meta-Analyses: The PRISMA Statement. PLoS Med 6(7): e1000097. doi:10.1371/journal.pmed1000097

For more information, visit: www.prisma-statement.org.

Page 2 of 2

For peer review only