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Effects of 20 mph interventions on a range of public health outcomes: A meta-narrative evidence synthesis

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ABSTRACT

Background: Road traffic injuries are a leading cause of preventable death globally, but can be reduced by introducing speed lowering interventions such as 20 mph or 30 km/h speed 'zones' and 'limits'. 'Zones' utilise physical traffic calming measures and 'limits' only utilise signage and lines. Transport is a social determinant of health and therefore such interventions may in/directly also impact on other health outcomes.

Aim: To investigate the effect of 20 mph speed 'zones' and 'limits' on a range of health outcomes, and to establish if there are differences in the effectiveness of 20 mph zones and 20 mph limits.

Methods: MEDLINE, EMBASE, Web of Science and Transport Research Information Service (TRIS) databases were searched [1983–January 2019) to identify relevant studies. Reference lists, relevant systematic reviews and the grey literature were also searched. Inclusion criteria: 20 mph 'zone' or 'limit' interventions: and public health outcomes (collisions, casualties, mode of transport, noise pollution, air quality, inequalities and liveability (e.g. physical activity and perceptions of safety)) and including a control/comparison group.

Results: Eleven studies were identified reporting nine 20 mph 'zone' and two 20 mph 'limit' interventions. 20 mph 'zones' were associated with a reduction in the number and severity of collisions and casualties; have less robust evidence of the effect on air pollution; and have the potential to indirectly impact physical activity and liveability through various mechanisms for change (although currently the evidence is lacking and requires further work). No significant

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associations were reported between 20 mph 'limits' and any public health outcome.
Conclusion: This review suggests 20 mph 'zones' are effective in reducing collisions and casualties. However, it provides insufficient evidence to draw conclusions on the effect of 20 mph 'zones' on pollution, inequalities or liveability. For 20 mph 'limits' more rigorous evaluations are required in order to draw robust conclusions.

1. Introduction

Previously published literature has made the case for transport as a social determinant of health and as a major factor influencing health inequalities (Marmot and Bell, 2012; Braveman et al., 2011; The Health Foundation, 2018). The impacts of transport are multi-faceted affecting health both directly and indirectly with collisions (i.e. an "incident" involving a person and at least one road vehicle) and casualties (i.e. a casualty is when a person/s is killed or injured during a collision) (World Health Organisation, 2009; Jackson and Cracknell, 2018) having the most detrimental effects.

Worldwide, across all age groups, casualties and collisions have been estimated to be the 10th leading cause of death, with the most vulnerable populations (i.e. pedestrians, cyclists, and motorcyclists) representing almost half of global fatalities (World Health Organisation, 2009; World Health Organisation, 2015; Jackson and Cracknell, 2018).

In addition to the apparent risk that transport poses to health through the number and severity of collisions and casualties, transport can also impact other health outcomes and health behaviours such as physical activity, sedentary behaviour, walking and cycling behaviour, liveability, pollution (both air and noise). Regarding physical activity and sedentary behaviour it has been widely acknowledged that both are major risk factors for morbidity and mortality, with walking and cycling being suggested as practical ways of meeting physical activity guidelines and reducing sedentary behaviour (Heath et al., 2006; Yang et al., 2010). However, both walking and cycling have been found to potentially be impeded by transport and transport networks as individuals may be, or perceive to be, unsafe when walking and/or cycling in their neighbourhoods forcing them to travel by motorised transport potentially reducing physical activity levels and increasing sedentary behaviour (Heath et al., 2006; Yang et al., 2010). Previous research has also shown that liveability can be negatively affected by motorised transport, as those living on streets with a high traffic volume were found to have a significantly lower number of friends and acquaintances which can result in increased feelings of social isolation and loneliness, and ultimately an increased likelihood of all-cause mortality (Hart and Parkhurst, 2011; Holt-Lunstad et al., 2015). Furthermore, transport has been established as a major source of air pollutants, exposure to which, has been linked to obesity, asthma, cardiovascular disease and cancer (Department for Environment Food and Rural Affairs, 2018; Royal College of Physicians and the Royal College of Physicians and Royal College of Paediatrics and Child Health, 2016). Air pollution affects everyone, although the impact is heightened by living and/or working near busy roads or deprived areas and pre-existing medical conditions (Department for Environment Food and Rural Affairs, 2018; Royal College of Physicians and the Royal College of Paediatrics and Child Health, 2016. In addition, noise pollution can also be harmful to both physical and mental health, with road transport being a leading source of environmental noise (Khreis et al., 2017). Such health impacts, also result in a source of considerable economic burden. In the UK, physical inactivity and air pollution are estimated to cost £1.5 and £20 billion respectively per year, when health and social care, employment absence and other factors are accounted for (Royal College of Physicians and the Royal College of Paediatrics and Child Health, 2016; British Heart Foundation, 2017). Consequently, calls have been made for modifications to the built environment and transport networks to alleviate the burden on health by implementing and/or improving: speed calming measures (speed limit signage, speed bumps, chicanes), cycle lanes, footpaths, pedestrian crossings etc. in order to improve health both directly and indirectly and to produce economic benefits (Sallis et al., 2009; Panter et al., 2016).

A common transport intervention is 20 mph speed restrictions which aim to not only reduce speed but also to improve road safety and the perception of road safety, and to reduce the number and severity of collisions and casualties. Research has shown that when drivers exceed the speed limit this causes 5% of all collisions and 15% of fatal crashes; and when pedestrians are hit by a car they have a gradually increasing risk of being killed at impact speeds up to 30 mph. However, between 30-40 mph this risk of fatality increases rapidly (3.5–5.5 times) (Department for Transport, 2017; Richards, 2010). Injuries to cyclists show a similar pattern with increased probability of fatality with higher vehicle speed. In high speed environments the risk of collisions for children and the elderly also increase due, respectively, to their underdeveloped and declining motion perception abilities and their inability to accurately judge speed and available crossing time (Wann et al., 2011; Lobjois and Cavallo, 2007; Webb et al., 2017). Speed restrictions also have the potential to increase physical activity primarily through the encouragement of walking and cycling behaviour, reduce sedentary behaviour and improve the liveability of an area. Further, spill over effects in adjacent and non-adjacent zones can occur due to the connected and interdependent components of transport and health. Slower speeds can provide individuals with improved perception of road safety in turn, encouraging active travel to work and school, recreational walking and cycling, and outdoor play (20's Plenty for Us, 2015a, b). 20 mph speed restrictions have also been reported to have the potential to reduce fuel consumption, and decrease air pollution, as standing traffic is reduced, allowing more efficient use of the available road space and more effective merging and filtering at junctions, reducing traffic queues (20's Plenty for Us, 2012; 20's Plenty for Us, 2010; Jones and Brunt, 2017). Therefore, 20 mph speed restrictions may have other public health impacts beyond road safety measures and the evaluation of their effectiveness as a public health intervention on a range of health outcomes is warranted.

Currently there are two main intervention approaches to implement 20 mph speed restrictions in urban areas. 20 mph 'zones' involve physical traffic calming measures such as road narrowing, speed bumps, central islands and chicanes which are designed to

slow vehicle speed and to ensure that the 20 mph speed limit is adhered to. These traffic calming measures can be used individually or in combination, therefore 20 mph 'zones' can differ between areas (Department for Transport, 2007). In contrast, 20 mph 'limits' involve only signage and/or lines which are used to alert drivers to the speed limit and do not involve physical infrastructure to decrease speed. The 20 mph speed restrictions are legally enforceable and may also be supported by awareness and education campaigns (Toy et al., 2014).

An umbrella review published in 2015 investigated the effect of 20 mph interventions on health and health inequalities (Cairns et al., 2015). However, this review did not distinguish between the impact of 20 mph 'zones' and 20 mph 'limits', and limited the outcomes to crashes, collisions, injuries, traffic speed and volume (Cairns et al., 2015). In addition, no evidence was presented for the impacts on socio-economic inequalities and the subsequent outcome/s (Cairns et al., 2015). For that reason, the authors concluded that "further controlled evaluations that specifically examine socio-economic effects" were required (Cairns et al., 2015). In addition, despite the rise in 20 mph speed restriction interventions, no review to date has investigated the distinct impact of 20 mph 'zones' and 20mph 'limits' on the wide range of possible public health outcomes and no attempts have been made to identify differences in the effectiveness of the two intervention approaches. Therefore, the current review was conducted to address this gap in the evidence and to further the field of transport and public health.

The aim of this review was to examine the effects of both 20 mph speed 'zones' and speed 'limits' on relevant public health outcomes. The review also assesses whether there are differences in the effectiveness of 20 mph 'zones' compared with 20 mph 'limits'.

2. Methods

The current study was reported in accordance with PRISMA guidelines (Moher et al., 2009). The initial searches established that studies were too heterogeneous to be combined in a meta-analysis as they used differing methodologies and varied outcome measures. Therefore, a systematic review using a meta-narrative method was undertaken. The meta-narrative method enabled the research team to implement a flexible and complementary approach to interrogate the field of 20 mph speed 'zones' and 'limits' (Wong et al., 2013) guided by the logic model framework of Rohwer et al. (2017). A meta-narrative method was implemented over a realist approach as it provided the research team with an appropriate method to summarise the included studies which conceptualised the 20 mph schemes differently and presented inconsistent methods and analysis procedures (Wong et al., 2013). This was thought to be a more suitable approach in comparison to a realist review where the focus is often on the theories of behaviour change (Otte-Trojel and Wong, 2016). Consequently, RAMESES guidelines and publication standards were implemented within the current review (Wong et al., 2013).

2.1. Meta-narrative review principles

A meta-narrative approach made it possible to review the subject of 20 mph 'zones' and 'limits' and to summarise results in a meaningful way (Wong et al., 2013). The current review implemented the six guiding principles of the meta-narrative method: pragmatism (guided by the most useful information for the intended audience); pluralism (the topic reviewed to consider multiple perspectives and viewpoints); historicity (the topic reviewed over time i); contestation (conflicting data considered); reflexivity (take time to reflect on the findings, individually and as a review team); and peer review (findings shown to an independent audience and the feedback used to guide further reflection) (Greenhalgh et al., 2005).

2.2. Search strategy

A review of the literature was conducted and each member of the team provided with the opportunity to present documents for inclusion (pragmatism) (Wong et al., 2013; Greenhalgh et al., 2005). Following the review, a comprehensive search strategy was devised for English language articles from 1983 (when the first 30kph/20mph 'zone' was implemented) to January 2019 in MEDLINE, EMBASE, Web of Science and Transport Research Information Service. Databases were searched using a tailored search strategy, consisting of the AND combination of the two main concepts, 20mph and health, and the OR combination of all keyword variations (Appendix 1). Reference lists and relevant systematic reviews were also searched for other potentially eligible studies. To complement these searches, grey literature was searched using: 20's Plenty, The Royal Society for the Prevention of Accidents (RoSPA), UK Roads Liaison Group, and Department of Transport.

2.2.1. Inclusion criteria

1. Natural experiments with quasi-experimental design; randomised control trials; controlled before and after studies; and interrupted time series.
2. Any age group, country and location.
3. 20 mph or 30 km/h speed 'zones' and 20 mph or 30 km/h speed 'limits' interventions (1 mile equates to 1.6 km).
4. Studies with a comparison group.
5. At least one public health outcome reported.

2.3. Screening of articles

To ensure pluralism, a multi-disciplinary team with differing expertise undertook independent screening of titles, abstracts and full texts for eligibility. Disagreements were resolved by discussion and consensus.

2.4. Data extraction

Data were extracted including: publication year; country; study design and duration; characteristics of the intervention and control groups; outcome(s); and results. The primary outcomes extracted were: road traffic collisions and casualties (any road user). Other outcomes extracted were: physical activity levels (walking and cycling), changes in mode of transport, noise pollution, air quality, inequalities, perceptions of road safety and liveability (The Health Foundation, 2018).

2.5. Quality appraisal

Quasi-experimental designs are considered methodologically weaker for establishing causation than randomised control trials and fewer tools exist to evaluate their quality. There are some tools available to assist with assessing quality of non-randomised study designs; however, these are not specific to the included study designs and there may be issues that they do not fully address (The Joanna-Briggs Institute, 2017; Sterne et al., 2016a,b; Sterne et al., 2016a,b). Therefore, using the elements of these tools as a guide, the following additional data was extracted to assess study quality: the duration (attrition bias), control site including location; selection and matching (selection bias); how the data were collected or measured (detection bias); selective or incomplete reporting of results (reporting bias); and any other attempts to minimise sources of confounding.

2.6. Evidence synthesis

Studies were presented by method and outcome and the results were combined in a narrative review. Schemes were categorised as: 1) 20 mph 'zones' and 2) 20 mph 'limits'. In addition, evidence was gathered by further sub-dividing results by: 1) collisions and casualties; 2) liveability including physical activity; 3) pollution; and 4) inequalities.

During the evidence synthesis stage a comparison was performed to review the differing meta-narratives and to ultimately interpret the included study findings. This stage of the review involved paradigm building and grouping by intervention approach (20

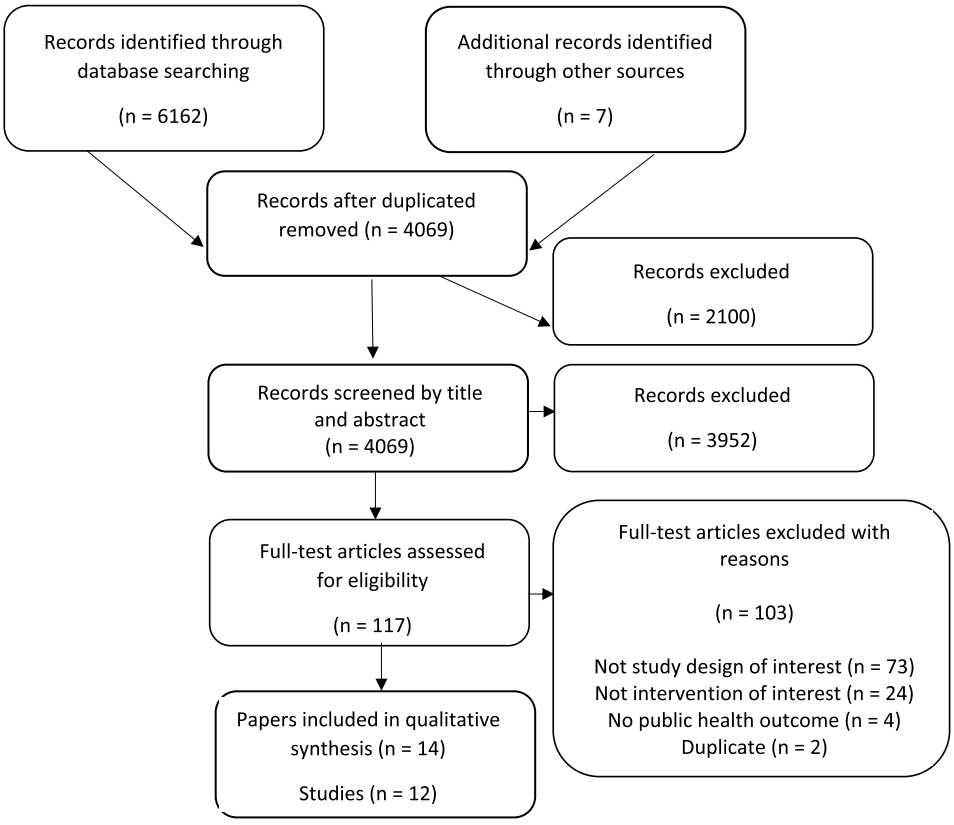

Fig. 1. Prisma flow diagram.

Table 1
Characteristics and results of studies examining the effect of 20 mph 'zones'.

Study	Study Design	Participants	Intervention	Control	Outcome(s)	Results			
						Collisions and casualties	Liveability	Pollution	Inequalities
Brilon and Blanke (1990, 1993) Germany	Controlled before and after 1–3 years before 1–3 years after	I: 6 towns in Germany (plus 1 pilot area) C: 1 town/area for each intervention (similar in structure and traffic density)	Extensive traffic calming measures:30 km/h speed limits, passive traffic calming measures and street modifications	No traffic calming	Seriously and slightly injured persons Collision costs Motor bikers involved in a collision Cyclists involved in a collision Pedestrians involved in a collision	63% ↓ in seriously injured persons: 49% ↓ in slightly injured persons; 40% ↓ in collision costs; 78% ↓ in motor bikers involved in a collision 17% ↓cyclists involved in a collision 25% ↓ in pedestrians involved a collision			
Engel and Thomsen (1992) Denmark	Controlled before and after 3 years before 3 years after	I: 223 km of 30 km/h streets C: All urban streets in Denmark that belong to local government authorities (18,935 km of streets in total)	30 km/h speed limit signage and area-wide traffic calming (speed humps, lateral dislocation and reduced road width)	No area wide traffic calming	Number of collisions and casualties Collisions and casualties per km of road	Sig. ($p < 0.05$) ↓ in no. of collisions (−24%, n = 77) and casualties (−45%, n = 88) in 30kmh streets; −18% (n = 150) collisions and −21% (n = 106) in the adjacent street sections 72% ↓ in no. of casualties per road user km; 78% ↓ no. of seriously injured casualties			
Grundy et al. (2009) UK (London)	Controlled interrupted time series Implementation date known for each zone, and roads classified for each financial year as pre-intervention, under construction and post implementation. Before and after periods varied, with a maximum after period of 15 years	I: Roads in a 20 mph zone in London, or would become part of one C: Areas adjacent to 20 mph zones, and all other roads in London	20 mph zones Zones marked with terminal signs (start and end) and with traffic calming measures (regular intervals throughout) Zone design varied depending on the local environment	No 20mph zones	All road traffic casualties All pedestrian casualties All cyclist causalities Powered two wheeled vehicle rider causalities All car occupants All road traffic collisions	20 mph zones: 41.9% (95% CI 36.0 to 47.8) ↓ 32.4% (95% CI 27.1 to 37.7) ↓ 16.9% (95% CI 4.8 to 29.0) ↓ 32.6% (95% CI 21.7 to 43.4) ↓ 52.5% (95% CI 42.5 to 62.4) ↓ 37.5% (95% CI 31.6%–43.4%) ↓ in all collisions			

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Table 1 (*continued*)

Study	Study Design	Participants	Intervention	Control	Outcome(s)	Results			
						Collisions and casualties	Liveability	Pollution	Inequalities
Li and Graham (2016) UK (London)	Doubly robust estimation (combination of outcome regression and propensity score models)	I: 234 treated zones in London C: 2844 potential control zones, refined to 1415 with matching	20 mph zones No further detail provided	No 20mph zones	Road traffic casualties	↓ in slightly injured casualties, 1.7 (10%); KSI, 0.73 (24%); and pedestrian casualties, 0.85 (21%)			
Vis et al. (1992) Netherlands	Controlled before and after (durations not provided)	I: 15 30 km/h zones C: Built up areas of the municipalities in which the zones are situated (excluding arterial roads)	30 km/h speed limit with traffic calming measures (speed humps, entrance constructions, turning bans, mini roundabouts and traffic island)	No area wide traffic calming	Road traffic collisions and casualties	5% ↓ in all collisions and 25% ↓ in collisions involving injury in the intervention areas (after adjustment for local trend)	Residents felt safer as they believed speed and the intensity of traffic had ↓		
Webster and Layfield (2007) UK (London)	Controlled before and after I: 5 years before, 1–5 years after C: 5 years before, average of 3 years after	I: 78 20 mph zones in London C: All unclassified roads in London	20 mph speed limit and area wide traffic calming (road humps, raised junctions, speed cushions, chicanes, raised footways)	No area wide traffic calming	Road traffic collisions Collision severity Road traffic casualties	↓ in annual collision frequency (−43%; $p < 0.01$) ↓ in annual frequency of KSI collisions reduced (−56%; $p < 0.05$) ↓ in annual casualty frequency (−46%; $p < 0.01$)			
Layfield et al. (2003) UK (Leeds)	Controlled before and after 18–24 months before, 1–6 months (monitoring period lasting at least 3 months)	I: 4 sites within a home zone in Leeds C: 1 site just beyond the home zone	Traffic calming measures on key streets in Leeds (road narrowing, 20mph signs, new shared road surface)	Road outside the home zone	Road traffic collisions Road traffic casualties Air quality impacts: NO2 and benzene concentrations	Injury collision frequency changed from 0.4 per year within the zone to 0 in the year 'after'; at junctions leading into the zone 2.2 per year injury collisions changed to 1 in the year 'after'; and 2.2 injury collisions per year on the perimeter roads outside the zone 'before' changed to 0 in the year 'after'	6% walked more often; 73% felt the home zone made walking more pleasant due to slower traffic (n = 6) and less traffic (n = 3); those who cycled thought the home zone made it more pleasant due to less traffic (n = 3) and good cycle surface (n = 2); no difference in activities in the street/outside the home due to the home zone for adults; children spontaneously riding bikes ↑ (22%–43%)	↓ daytime traffic noise in Leeds; little change for benzene and NO2 before and after in Leeds; the control site and one intervention site showed slight ↓ (−5% and −10% respectively), the 3 other intervention sites showed ↑ (2–43%); relative to the control site, benzene concentration ↑ slightly at intervention sites. All findings were non-sig.	

(*continued on next page*)

Table 1 (*continued*)

Study	Study Design	Participants	Intervention	Control	Outcome(s)	Results			
						Collisions and casualties	Liveability	Pollution	Inequalities
							and roller skating/ skateboarding ↑ (11%–19%) after the home zone		
Webster et al. (2006) Seven sites across UK (England) Leeds as presented above is included as 1 of the 7 sites	Controlled before and after 5 years before 1–5 years after	I: 7 sites 20mph traffic calming zones	Traffic calming measures within 7 sites across England	No area wide traffic calming	Road traffic collisions Air quality impacts: NO2 and benzene concentrations	↓ from 0.54 collisions per site per year to 0.24 collisions per site per year	No change in walking; 44% thought it was more pleasant due to less traffic (4%) and slower traffic (2%); cycling did not change although 30% of cyclists thought it was more pleasant; in the street/outside the house there was an overall slight ↓ in time spent outside the home		
Owen (2005) UK	Controlled before and after 2 zones: consecutive 1 month periods for 5 and 9 months before, 12 months' after 4 zones: single monthly averages for an undefined period before, 3 and 12 months after	I: 6 20mph zones in NW England, 3 sites per zone C: 1 site per zone, beyond the influence of the zone	0.5 × 0.5 km 20mph zones using signage and speed humps	Roads beyond the influence of the 20mph zones	Air quality impacts: NO2 and benzene concentrations			In one zone concentrations of NO2 ↓ at all sites, including the control, by between 4% and 13%; concentrations of benzene↓ (10%-)35% at all sites including the control. At a second zone, NO2 concentrations ↑ by 1%–10% at all sites including the control; concentrations of benzene ↑ at all sites, including the control (19%–36%). Changes were small ($p > 0.05$).	
Steinbach et al. (2011) UK (London)	Controlled interrupted time series Known implementation date for each zone; roads	I: Roads in 20 mph zone in London, or would become part of one C: Areas adjacent	20mph zones Zones marked with terminal signs (start and end of the zone), with traffic calming	No 20mph zones	Inequalities: The effect of 20 mph zones on road casualties across				Similar effect across all quintiles of socioeconomic deprivation; 38.3% (95% CI

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Table 1 (*continued*)

Study	Study Design	Participants	Intervention	Control	Outcome(s)	Results			
						Collisions and casualties	Liveability	Pollution	Inequalities
	classified for each financial year as pre-intervention, under construction and post implementation Before and after periods varied, with a maximum after period of 15 years	to 20 mph zones, and all other roads in London	measures at regular intervals throughout The design of each zone varied depending on the local environment		socioeconomic levels				31.5%–45.0%) ↓ in all casualties in the most deprived quintile (Q5) and a 41.8% (21.0%–62.6%) ↓ in the least deprived quintile (Q1) (p = 0.62 for trend across deprivation quintiles) Trend % ↓ in all casualties on all roads, was greater in the least deprived areas compared with the most deprived areas ($p < 0.001$) Prevented more casualties per km of road in most deprived areas compared with least deprived areas (0.22/km in Q1 compared with 0.01/km in Q5)

mph 'zones' and 20 mph 'limits') and outcomes (Wong et al., 2013).

3. Results

3.1. Study characteristics

A total of 6169 studies were identified including seven studies/reports from manual searches and grey literature (Fig. 1). Following duplicate removal (n = 2100), 4069 studies were included for title/abstract screening. After initial screening, 117 studies met the eligibility criteria and following full text screening 13 papers reporting 11 studies, met the inclusion criteria (Atkins et al., 2018; Brilon and Blanke, 1993; Brilon and Blanke, 1990; Grundy et al., 2009; Steinbach et al., 2011; Webster et al., 2006; Layfield et al., 2003; Engel Thomsen, 1992; Webster Layfield, 2007; Li Graham, 206; Vis et al., 1992; Owen, 2005; Gaca et al., 2016).

Included studies were all European and published 1990–2018: UK (6); Demark (2); the Netherlands (1); Germany (1); and Poland (1). Four additional reports were found in the grey literature (Manchester City Council, 2017; Pilkington et al., 2018; The City of Edinburgh Council, 2013; Department for Transport, 2010). These were not included within the review but reported findings that warranted review were noted. Of the included studies, four were reported by more than one publication; these provided further details regarding the methodology, intervention and/or additional outcomes. Two publications reported the effect of 30 kmh 'zones' on six towns and a pilot town in Germany and within the current review they were considered as one study (Brilon and Blanke, 1993; Brilon and Blanke, 1990). A study that examined 20 mph 'zones' in London was reported in two publications each investigating different outcomes and were both presented separately within this study (Grundy et al., 2009; Steinbach et al., 2011). The results from a home zone (i.e. a shared space scheme where streets are designed for all road users) in Leeds was presented in a Transport Research Laboratory (TRL) report on pilot home zone schemes in the UK (Webster et al., 2006) but is described in more detail in an evaluation report (Layfield et al., 2003); both were presented separately in the current review (Table 1). The two final reports were published in 2018 with findings from the UK (Atkins et al., 2018) and Poland (Gaca et al., 2016).

3.2. 20 mph or 30 kmh 'zones'

Nine of the included studies examined the effect of 20 mph 'zones' (Table 1).

3.2.1. Collisions and casualties

Overall, the nine included studies indicated that 20 mph 'zones' are associated with a reduction in the number and severity of collisions and casualties. Brilon and Blanke (1990, 1993) reported that the introduction of traffic calming measures was associated with an average 63% reduction in seriously injured persons; a 49% decrease in slightly injured persons; a 40% decrease in collision costs; a 78% decrease in motor bikers involved in a collision; a 17% decrease in cyclists involved in a collision; and a 25% decrease in pedestrians involved in a collision (Brilon and Blanke, 1990, 1993). Similarly, Engel and Thomsen (1992) found 30 kmh streets were associated with a reduction in the number of collisions (24%, n = 77) and casualties (45%, n = 88) and changes were also observed in the street sections just outside the 30 kmh zones with an 18% reduction in collisions and a 21% reduction in casualties (Engel and Thomsen, 1992). Additional findings showed collisions and casualties were related to the number of road users (including pedestrians, pedal cyclists and moped riders) kilometres travelled in each street; with the main effect showing a significant reduction in the number of casualties per road user km, (72% [95% CI -4 to −92%]) and a significant reduction in the number of seriously injured casualties (78% [95% CI -26 to −93%]) (Engel and Thomsen, 1992).

Grundy et al. (2009) reported that 20 mph 'zones' were associated with reductions of: 41.9% (95% CI 36.0 to 47.8) in all casualties; 32.4% (95% CI 27.1 to 37.7) in all pedestrian casualties; 16.9% (95% CI 4.8 to 29.0) in all cyclist casualties; 32.6% (95% CI 21.7 to 43.4) in all causalities of powered two wheeled vehicle riders; 52.5% (95% CI 42.5 to 62.4) in all car occupant causalities; and 37.5% (95% CI 31.6 to 43.4) in all collisions. The greatest reductions were found in the killed or seriously injured (KSI) category and in those aged 0–15 years. In addition, an 8.0% (95% CI 4.4 to 11.5) reduction in casualties and a 7.4% (95% CI 3.8 to 11.0) reduction in collisions were also observed in areas adjacent to the 20 mph 'zones' (Grundy et al., 2009). Li and Graham (2016) reported that the 20 mph 'zones' had a consistently significant impact on casualties, reducing by number. Specifically, they concluded, that 20 mph 'zones' were associated with reductions in slightly injured casualties (1.7 [10%], KSI (0.73 [24%]); and pedestrian casualties (0.85 [21%]) (Li and Graham, 2016). Vis et al. (1992) (62) reported a 5% reduction in collisions with the implementation of 30 kmh 'zones', after adjustment for local trend. This reduction was greater (25%) in collisions involving injury.

Webster and Layfield et al. (2003) reported highly statistically significant ($p < 0.01$) reductions in collision and casualty frequency associated with 20 mph 'zones' (43% and 46% respectively) before correction for local trends. When full allowance is made for trends on unclassified roads, these values are revised to a 41% reduction in collisions and a 45% reduction in casualties (Webster and Layfield et al., 2003). This adjustment assumes the introduction of 20 mph 'zones' has had no effect on the unclassified roads, whereas in reality they will have contributed to this underlying trend. The study therefore suggests that the effect of 20 mph 'zones' is better interpreted as bringing about a reduction of somewhere between the two values (a 41–43% reduction in all collisions and a 45–46% reduction in all casualties) (Webster and Layfield et al., 2003). Statistically significant reductions were also observed in pedestrian, cyclist, powered two wheeled vehicle and car occupant casualties. Layfield et al. (2003) found that the 'before' frequency of collisions within the 'zone' was 0.4 per year versus 0 in the year 'after' the 'zone'; 2.2 per year at junctions leading into the 'zone' versus 1 in the year 'after'; and 2.2 per year on the perimeter roads outside the 'zone' 'before' versus 0 in the year 'after'.

Webster et al. (2006) detailed results from a seven site (Leeds, Manchester, Sittingbourne, Magor, Plymouth, Nottingham, Ealing)

Table 2
Characteristics and results of studies examining the effect of 20 mph 'limits'.

Study	Study Design	Participants	Intervention	Control	Outcome(s)	Results			
						Collisions and casualties	Liveability	Pollution	Inequalities
Gaca et al. (2016) Poland	Controlled before and after At least 1 year before and 1 year after	I: 10 Tempo 20 residential area locations, 35 Tempo 30 speed limit locations	Tempo 20 and Tempo 30 zones	Untreated area in region under analysis	Road Traffic collisions Road Traffic causalities	Tempo 20 and Tempo 30 zones associated with ↓ in KSI casualties (average rate of 27%); no positive effects for collision reduction			
Atkins et al. (2018) UK 12 schemes	12 20 mph case study schemes in England with comparator areas with a 30 mph speed limit	I: 12 schemes in England: Walsall (Rushall), Winchester (Stanmore), Liverpool (Area 7), Liverpool (Area 2), Middleborough, Calderdale (Phase 1) Nottingham (Bestwood), Brighton (Phase 2), Portsmouth Chichester, Brighton (Phase 1), Winchester (City centre) C: Three comparator areas are used to identify background trends in speeds on 30mph roads with similar characteristics to the 'core schemes'; and regional-based data is used to identify background trends in collisions and casualties on similar 30mph roads.	12 schemes lowered speed limit from 30 mph to 20 mph through signage and road markings, supporting community engagement activities to raise awareness and encourage support (none involved the introduction of physical traffic calming measures or changes to the street design)	3 comparator area used to identify background trends in speeds on 20mph roads with similar characteristics to the 'core schemes' and regional-based data used to identify background trends in collisions and casualties on similar 30 mph roads	Road Traffic collisions Road Traffic casualties Perceptions of walking and cycling Mode of transport Impacts on community, local economy, environment and health	Insufficient evidence to conclude a sig change in collisions and casualties following the introduction of 20mph limits in residential areas, in the short term For city centre the comparator analysis shows that Brighton Phase 1 is the only case study area where the change in collisions and casualties, relative to the 30mph comparator area was sig ($p < 0.001$). Overall, no sig change in the short term in collisions and casualties, in the majority of the case studies	Small (but sig) ↑ in proportion stating that they have ↑ their use of active travel mode A minority of residents felt that keeping traffic below 20mph made it more likely they will walk (16%; CI 13.9%–18.1%) or cycle (9%; CI 7.4%–10.6%) to local places rather than use the car Few residents (3%) believed that the new speed limit meant that people are avoiding the area and are less likely to use local shops/ amenities 69% residents agreed that 20 mph limits were beneficial for cyclists and pedestrians; 69% cyclists and 89% pedestrians agreed 20 mph limits were beneficial	No primary data on air quality, greenhouse gas emissions, noise levels was collected	

traffic management scheme including the study previously presented in Leeds. Road traffic injury collisions were analysed across the seven study sites with findings showing a reduction from 0.54 to 0.24 collisions per site per year. Self-reported collisions and near misses were also found to decrease after installation of the traffic calming 'zones' (Webster et al., 2006). Although some of these findings are statistically significant, they are rare events, and random fluctuations may be impacting the significance.

3.2.2. Liveability including physical activity

Layfield et al. (2003) and Webster et al. (2006) reported walking and cycling changes following the implementation of schemes in Leeds (Layfield et al., 2003) and across seven English sites (including Leeds) (Webster et al., 2006). Regarding walking, for most respondents the introduction of the scheme did not make a difference because levels of walking were already high. However, in Leeds 73% of participants reported that walking in the home zone was now more pleasant (Layfield et al., 2003), while the figure was 44% overall across the seven sites (Webster et al., 2006). The reasons reported for walking being more pleasant were linked to slower traffic and less traffic. Approximately 21–25% reported to own a bicycle with 'use' being found to be low at both time points (Leeds and wider study areas); implementation of 20mph 'zones' made no difference. However, for those who did cycle in Leeds the scheme made cycling more pleasant for 50% (approximately) due to less traffic and good cycle surface, in Ealing 60% thought cycling was more pleasant and 10% thought it was less pleasant. Of the children who cycled 22–27% said they cycled more due to scheme implementation and 57–73% said they rode about the same (lower levels overall across the seven sites).

Both studies also reported activities in the street/outside the home for adults and children. Following the implementation of the home zone the majority of adults said the zone made no difference to the amount of time they spend outside; and overall there were only little changes in the activities of children. The proportion of children reporting "spontaneously" riding bikes in Leeds increased substantially from 22% to 43% and the use of roller skates and skateboards also increased from 11% to 19%. In addition, Vis et al., (1992) reported that residents felt safer as they believed that speed and the intensity of traffic had declined.

3.2.3. Pollution

Three studies (Webster et al., 2006; Layfield et al., 2003; Owen, 2005) examined the effect of 20 mph 'zones' on air quality by measuring benzene and nitrogen dioxide (NO_2) in ambient air before and after implementation (Table 1). For similar periods, without missing data, Layfield et al. (2003) found marginal increases in benzene at intervention sites compared with the control site and marginal decreases in NO_2 at intervention sites, compared with the control site. The concentrations of benzene and NO_2 were below Air Quality Standards (5μg/m3 and 40 μg/m3 respectively) at all sites, both before and after implementation (Department for Environmental Food and Rural Affairs, 2018).

Owen (2005) found increases in benzene and NO_2 at one intervention site, and decreases in both at a second site (Owen, 2005). All observed changes in both studies, were small and not statistically significant.

3.2.4. Inequalities

Only one study looked at the effect of 20 mph 'zones' on inequalities (Table 1) (Steinbach et al., 2011). It found that 20 mph 'zones' have similar effects across all quintiles of socio-economic deprivation in terms of pedestrian, KSI and all casualties. Similarly, areas adjacent to 20 mph 'zones' also experienced a decline in casualties that was consistent across quintiles of socioeconomic deprivation. A higher number of casualties usually occurs in deprived areas, and as such 20 mph 'zones' have been implemented in the most deprived areas. Therefore, the number of casualties prevented by 20 mph 'zones' was significantly greater in the most deprived areas compared with the least. Despite this, the underlying trend of casualty rate reduction on all roads is greatest in the least deprived quintile. However, the study concluded that 20 mph 'zones' may be effective in reducing this widening of inequalities.

3.3. 20 mph or 30 kmh 'limits'

Two included studies examined the effect of 20 mph 'limits' (Table 2) (Atkins et al., 2018; Gaca et al., 2016).

3.3.1. Collisions and casualties

Both studies, showed, that 20 mph 'limit' were effective in improving road safety. Gaca et al. (2016) used crash modification factors (CMF) scores to evaluate how 30 kmh speed 'limits', and other road safety measures and designs, affect road safety (Gaca et al., 2016). To determine the potential safety effect of an intervention the change in the number crashes was compared. A CMF score was then applied to the number of crashes before the intervention to calculate the expected number of crashes after implementation at a specific site. The study stated that area speed limits were effective in improving road safety. A reduction in KSI casualties was reported following the introduction of 20 mph and 30 mph 'zones' (CMF [-] of 0.65 in treated group, compared with 0.74 in the control group). However, no positive effects on collision reduction were observed. No confidence intervals or hypothesis tests were presented. It was also stated that area speed limits were especially effective when combined with traffic calming measure, however, it was not clear how this was calculated.

Atkins et al. (2018) evaluated 12 case study schemes comparing them to comparator areas with 30 mph speed 'limits'. Regarding public health outcomes, the report showed that there was insufficient evidence to conclude that there was a significant change in both collisions and casualties in 20 mph speed 'limit' areas. It was noted that the number of both collisions and casualties had declined in the 20 mph areas but this was also the case in the 30 mph areas (Atkins et al., 2018).

Table 3
Quality appraisal and risk of bias in included studies.

Reference	Study design	Duration	Control	Data source	Other
Atkins et al. (2018) UK (England)	12 20 mph case study schemes in England and various comparator areas with a 30 mph limit	Varied in each of the schemes. 11 schemes implemented March 2012–June 2015 and 12th scheme implemented before 2010	Comparator sites with 30 mph speed limit; 3comparator areas used to identify background trends in speeds on 30mph roads with similar characteristics to the 'core schemes'; regional-based data used to identify background trends in collisions and casualties on similar 30mph roads	Questionnaires with 2170 residents living in or near the 20 mph limits, 1256 drivers living outside the case study areas and 1655 cyclists and 352 motorcyclists nationwide. Interviews (177 non-residents), 9 focus groups, stakeholder interviewers, analysis of speed outcomes based on GPS vehicle data, spot speed data and analysis of safety outcomes based on DfT road accident statistics (STATS19)	Time frame of each case study scheme unclear
Brilon and Blanke (1990, 1993) Germany	Controlled before and after	Varied in each of the towns 1–3 years before, 1–3 years after	Towns/areas similar in structure and traffic density, but where no traffic calming measures were implemented Each intervention town had 1 control area	Collision data obtained from police records	Unclear which towns included a 30 km/h speed limit; intervention areas considered as a whole, although only parts included a 30 km/h zone; additional analyses limited to traffic calmed streets within intervention area, but again only some of these streets included a 30 km/h zone; specific effect of 30 km/zones not distinguished in the results
Engel and Thomsen (1992) Denmark	Controlled before and after	3 years before, 3 years after	All urban streets in Denmark that belong to local government authorities (18,935 km of streets)	Collision and causality data obtained from police records	
Gaca et al. (2016) Poland	Controlled before and after	At least 1 year before and 1 year after	Untreated areas in region under analysis	Collision and causality data obtained from police records	Study included 5, 15 km/h streets alongside 39, 30 km/h streets; effect of each not distinguished in the results
Grundy et al. (2009) UK (London)	Controlled interrupted time series	Before and after time periods unclear. Varied for each road, maximum after period was 15 years	All areas adjacent to 20 mph zones and all other roads in London	Police STATS19 data, linked to road segment data through a GIS. Using the 2004 index of multiple deprivation for the lower super output area (LSOA), road segments categorised by deprivation quintile	Unable to account for possible impact of other road safety initiatives. However, it was possible that this confounding would affect both intervention and control roads
Layfield et al. (2003) UK (Leeds)	Controlled before and after	18–24 months before, 1–6 months after with each monitoring periods lasting at least 3 months	1 site, just beyond influence of zone	Interview surveys (children and adults), automatic traffic counters and tube detectors, police STATS19 data and noise and air quality measures (Leeds only)	Before and after periods undertaken at the same time of year to minimise seasonal effects
Li and Graham (2016) UK (London)	Doubly robust estimation (combination of outcome regression and propensity score models)	3 years before, 3 years after	As 20 mph zone may affect neighbouring areas, those within 150 m of each 20 mph zones were excluded as potential controls. 2844 potential control zones were selected, refined to 1415 with matching to improve the balance of characteristics between intervention and control group. Population density, green space and	Collision data obtained from police records (STATS19). Locations were recorded using the British National Grid coordinate system and GIS software. The index of multiple deprivation (IMD) was obtained from the office for the Deputy Prime Minister). Road network information was obtained from Ordnance Survey (OS) Meridian	Associations between casualties and road network characteristics addressed via a detailed panel data set on road network design

(*continued on next page*)

Table 3 (*continued*)

Reference	Study design	Duration	Control	Data source	Other
			road traffic injuries at baseline were included		
Owen (2005) UK	Controlled before and after	2 zones: consecutive 1 month periods for 5 and 9 months before, 12 months' after. 4 zones: single monthly averages for an undefined period before, 3 and 12 months after	6 control roads (1 per zone) beyond the influence of the 20 mph zone.	Diffusion tubes (NO2) and thermal desorption tubes (benzene)	Seasonal average was calculated for comparison
Steinbach et al. (2011) UK (London)	Controlled interrupted time series	Before and after time periods unclear. Varied for each road, maximum after period is 15 years	All areas adjacent to 20 mph zones and all other roads in London	Police STATS19 data, linked to road segment data through a GIS. Using the 2004 index of multiple deprivation for the lower super output area (LSOA), road segments were categorised by deprivation quintile	Unable to account for possible impact of other road safety initiatives. However, possible that this confounding would affect both intervention and control roads
Vis et al. (1992) Netherlands	Controlled before and after	Before and after periods not provided	Built up areas of the municipalities in which the zones were located (excluding arterial roads)	Not stated	Observations not always made at similar times, traffic situations and weather conditions before and after implementation
Webster and Layfield (2007) UK (London)	Controlled before and after	I: 5 years before, 1–5 years after C: 5 years before, average of 3 years after	All unclassified roads in London	Data on location, installation date and measures use in each zone was obtained from London Boroughs. Collision and casualty data was obtained from the London Accident Analysis Unit (LAAU).	
Webster et al. (2006) 7 sites across England	Controlled before and after	18–24 months before, 1–6 months after with each monitoring period lasting at least 3 months	Sites just beyond influence of zone	Interview surveys (children and adults), automatic traffic counters and tube detectors, police STATS19 data and noise and air quality measures (Leeds only)	Before and after periods undertaken at the same time of year to minimise seasonal effects

3.3.2. Liveability including physical activity

Only one study reported outcomes relating to liveability. Of residents, drivers and exiting cyclists (n = 1965 (all schemes) 69% felt the speed limits were thought to be beneficial for both cyclists and pedestrians and 60% felt the limits "provided a safer environment for walking and cycling" (Atkins et al., 2018). Of those who currently cycled 66% felt 20 mph provide a safer environment for cycling. The process and impact report also showed that there has been a small (but significant) increase in the proportion stating that they have increased their use of active travel mode; but a minority said that keeping traffic below 20mph makes it more likely they will walk (16%) or cycle (9%) rather than drive (Atkins et al., 2018).

3.4. 20 mph speed 'limits' - grey literature

Additional grey literature was found for before and after evaluations of 20 mph speed 'limits'. These interventions were implemented in Manchester (Manchester City Council, 2017), Bristol (Pilkington et al., 2018), Edinburgh (The City of Edinburgh Council, 2013) and Portsmouth (Department for Transport, 2010). The studies were not included within the main body of the current review as they did not include a control group; however, it was felt that it would be beneficial to highlight their findings.

The interventions showed on average 20 mph 'limits' were associated with a reduction in vehicle speeds of 0.7mph, −29% (673–444) citywide rate of pedestrian collisions and −42% (475–274) citywide rates of cyclist collisions. However, casualty figures could not be reported confidently, due to the time frame (Manchester) (Manchester City Council, 2017). In Bristol comparison data for speed but not for public health outcomes was presented (which could not be included within the main body of the review); found speed reduced significantly by 0.8–2.7mph dependent on the measurement method (controlled) (Pilkington et al., 2018). In addition, casualties reduced, fewer residents were disturbed by traffic noise and walking to work increased 17.5–18.9%. Furthermore, the number of people driving to work decreased by 53-44%, and the number of cyclists increased by 11–15% following limit introduction (Pilkington et al., 2018).

Within Edinburgh's Pilot evaluation in one part of the city, reports showed speed reduced on average by 1.9mph on 20mph roads (The City of Edinburgh Council, 2013). Figures for casualties/collisions could not be reported due to the monitoring time frame although support for the scheme increased from 68% before to 79% after (The City of Edinburgh Council, 2013). Finally, in Portsmouth speed reduced by −1.3mph; collisions fell by 21% per year; casualties fell by 22% per year; and walking (+9.2%) and cycling (+8.0%) increased (The City of Edinburgh Council, 2013).

3.5. Quality and risk of bias in the included studies

Overall, the included studies were generally at a high risk or unclear risk of selection bias and bias due to confounding (Table 3). This may be due, in part to the natural experiment study design, as the investigators had limited control over the intervention and control areas. In terms of selection bias, three studies reported matching of the control group, although details are only provided by one study. The control groups for the remaining studies (n = 8) were untreated roads in the areas under analysis. The majority of studies (n = 7) used routinely collected police data, therefore, risk of detection bias is low as the data were produced and maintained by an external source. The source of data was unclear for two studies, and in a further two studies, measurements were taken by the study team. In addition, the before and after periods varied widely between studies: the majority of studies included at least one year before and after data (n = 7). In terms of reporting bias, several studies did not clearly report their data, statistical methods or how conclusions were reached, and one study excluded an intervention area from analysis because it had shown an increase in collision figures. Three studies combined an intervention of interest with another intervention, and as insufficient data were provided to distinguish the effects of the intervention of interest, it was difficult to interpret the results of these studies in the context of this review. Other potential sources of bias, or attempts to minimise confounding are noted in Table 3.

4. Discussion

The aim of the current review was to investigate the effect of 20 mph speed 'zones; and limits on public health outcomes and to establish differences in the effectiveness of zones compared with limits.

Based on the evidence, the effect of 20 mph 'zones' on public health outcomes is positive. In particular, there were significant reductions in collisions and/or casualties. In regards to 20 mph 'limits', the evidence based was more limited and results were not as clear, and limited in regards to their examination of liveability, pollution or inequalities.

20 mph 'zones' were found to have the potential to significantly reduce road traffic deaths and injuries. However, a concern is that 20 mph 'zones' will lead to a relocation of collisions rather than prevention. This is addressed in several studies, which also report a reduction in collisions and casualties in areas adjacent to 20 mph 'zones', suggesting that collision migration is unlikely (Grundy et al., 2009; Engel and Thomsen, 1992; Webster and Layfield, 2007). In addition, the included studies report a general reduction in collisions and casualties in control groups, but to a lesser extent than intervention areas. This may suggest that other road safety interventions are in place simultaneously, highlighting the need for a control group, as the comparison allows the results to more accurately reflect the effect of 20 mph 'zones'.

Regarding pollution, less robust evidence of the effect of 20 mph 'zones' on air pollution was found. A potential reason may be due to the fact that speed, driving style and congestion play a role in vehicle emissions and some vehicles operate most efficiently at higher speeds, so low speeds may increase emissions whilst decreasing efficiency (Transport for London, 2018). Conversely, slower speeds may promote smoother driving, meaning reduced acceleration and braking, in turn having a positive effect; and the health

impact of small increases in air pollutants may be outweighed by the reduced risk of injuries and death by decreased speed. Air quality is a contributor to several of the United Nations Sustainable Development Goals (SDGs) (4), including SDG 3: Good Health and Wellbeing, SDG 11: Sustainable Cities and Communities and SDG 15: Life on Land (United Nations, 2016). Therefore, interventions that improve air quality are vital to achieving these goals. It is clear that the effect of transport on vehicle emissions can be complex and conflicting, and so further investigation is required to fully understand the effect of 20 mph 'zones' on air quality and the mechanisms by which such change is brought about. This review found that on a small scale, the introduction of 20 mph 'zones' had no significant effect on ambient air quality in terms of NO_2 and benzene. Finally, it should be noted that due to the difficulty in measuring air pollution in comparison to other public health outcomes this should be considered and reflected upon as a factor in the quality of the evidence.

In relation to liveability, results showed for included studies, participants reported to walk more and found the environment more pleasant due to slower and less traffic. Neighbourhood 'pleasantness' also increased for those who already cycled and an increase was seen in children spontaneously cycling. 20 mph speed 'zones' have the potential to indirectly impact physical activity and liveability through various mechanisms for change although currently the evidence is lacking and requires further work. Similarly, research is lacking in regards to 20 mph restrictions and health inequalities; only one included study concluded that 20 mph 'zones' are equally effective in reducing casualties across all quintiles of socioeconomic deprivation, and may serve to alleviate the widening of inequalities. While further research is required, 20 mph 'zones' may have potential in helping to improve liveability and to achieve SDG 10: Reduced Inequalities (United Nations, 2016).

4.1. Comparison of 20 mph speed 'zones' and 'limits'

To date, no review has performed a comparison between speed limits and zones. As discussed, the evidence suggests that 20 mph 'zones' are effective. However, there was a lack of evidence on the effectiveness of 20 mph speed 'limits'. Only two studies reported the effects of 20 mph speed 'limits' (signage). Gaca et al., 2016 reported no significant effect on collisions, although did find that 20 mph speed 'limits' were associated with a reduction in KSI casualties. The sample was small and based on only lower class roads, therefore the results may not be applicable in a wider context. Atkins et al. (2018) reported that although collisions and casualties decreased the time was too short to see significant changes when compared with control/comparison sites. Grey literature highlighted the results of four additional interventions which appear to have positive public health outcomes. These findings should be considered and reviewed within the context of the current evidence although taken into consideration they had no control/comparison sites, so it is difficult to isolate specific intervention effects.

More research has been carried out for 20 mph 'zones' as opposed to 20 mph 'limits'. This is not to say that 20 mph speed 'limits' are not effective in improving public health outcomes and current research would indicate that they have the potential to be successful, but more work is required to evaluate the schemes with comparison/control sites in order to isolate the effect(s) of the interventions in relation to public health outcomes.

4.2. Completeness and applicability of evidence

The included studies were all implemented within urban areas in high income countries with results being found to be consistent across locations. Further research would however be recommended in order to determine if the results are applicable to rural areas; which tend to have higher speed limits (60 mph), which is often unsuitable for the design and condition of the road, particularly considering their use by vulnerable road users. In addition, speeding often occurs in villages on major rural roads despite a reduced speed limit on through roads (Department for Transport, 2007). Research is also required in low-middle income countries which make up a large proportion of road traffic injuries, due in part to the rapid increase in vehicle use that has not been matched with policy updates, infrastructure improvements and enforcement (World Health Organisation, 2015). Traffic calming measures have previously been shown to be effective, in both rural areas[58] and low-middle income countries (Staton et al., 2016). Therefore, it is possible that 20 mph 'zones', particularly in areas with high rates of speed related collisions, would be beneficial in reducing collision and casualty rates.

Despite the popularity of 20 mph 'zones' and 'limits', many of the included studies were published in the 1990s and 2000s (20's Plenty for Us, 2015a, b). Changes in infrastructure and traffic volume, (increase in the number of roads, car users and cyclists), since this time, bring into question the applicability of the results; only four studies (30%) were from the last 10 years (Department for Transport, 2017).

4.3. Quality and limitations of the evidence

The quality of the evidence is dependent on the quality of its included studies. This review found no randomised controlled trials that met the inclusion criteria, and all included studies were quasi-experimental design, with the majority being controlled before and after studies. This introduced potential biases as little detail was provided on selection and matching of control groups, and therefore their characteristics may differ from those of the intervention group. One study used a doubly robust estimation which included extensive matching of the control streets to the intervention streets. While the results were consistent with the reductions reported by others, the estimates were smaller (Li and Graham, 2016). This could be due to selection bias in the other studies leading to an overestimation of the effects.

With a few exceptions, where details of the study periods were not provided (Vis et al., 1992) or where stated that measurements

were undertaken at the same time of year (Layfield et al., 2003; Owen, 2005), all studies included before and after periods of at least one year; this is important due to the seasonal variation in traffic patterns. It should be noted that it was not always possible to determine how the results from each study were obtained and several studies did not provide confidence intervals or significance data. Furthermore, some of the studies did not examine 20 mph 'zones' exclusively (Brilon and Blanke, 1990, 1993; Engel and Thomsen, 1992; Gaca et al., 2016).

As mentioned in several of the studies, a limitation is inaccurate and incomplete data in police records. There is typically an under reporting of collisions in police records, and misclassification of collisions. Furthermore, the studies were unable to account for other road safety measures, in either the control or intervention group (e.g. traffic volume and weather). However, this is likely to be the same across intervention and control areas. Few studies measured the negative impact of such interventions or captured unintended consequences. For example, we could hypothesise that these road safety measures may affect trip making, mode choice and route choice. Further, we were unable to draw conclusions regarding the impact of collision migration to non-adjacent zones. Such measures should be considered in future studies.

4.4. Potential biases and limitations of this study

The number of relevant studies may have been limited by English language. The high proportion (50%) of studies from the UK may be evidence of this, particularly considering the popularity of such zones in residential areas across Europe (20's Plenty for Us, 2015a, b). Secondly, it should be noted that even though a comprehensive search was undertaken, publication and selection biases may have been possible. This relates to the fact that many studies on road traffic safety, are found in grey literature in the form of reports by charities, governments and local councils, rather than peer reviewed papers, and many are publicly unavailable. In addition, the study design and reporting style varied between studies and relevant data were not always provided or able to be extracted. Most studies included only short follow-up periods of one year. Longer follow-up periods are required in order to mitigate the effects of regression to the mean. Evidence synthesis was therefore presented narratively, thus the conclusions are less certain.

5. Conclusions

This review found that 20 mph 'zones' appear to be effective, in particular in reducing the number and severity of collisions and casualties. However, it provides insufficient evidence to draw robust conclusions on the effect of 20 mph 'zones' on liveability, air quality and inequalities, or on the effect of 20 mph speed 'limits' on these public health outcomes. Therefore, regarding the comparison of the effects of 20 mph 'zones' in comparison to 20 mph 'limits', 'zones' appear to be more effective although as the work in this field is limited more research is required to determine a direct comparison with speed limits as the majority of current research is limited by lack of control/comparison sites and time frames.

In practice, the implementation of 20 mph 'zones' appears promising, although based on this review may be restricted to towns and cities in higher income countries. Further research is required in order to ascertain the extent of their effectiveness. In addition, their future and continued benefit may also be limited in those settings where they have already been widely implemented (Grundy et al., 2009; Steinbach et al., 2011).

This review highlights the need for high quality controlled evaluations, to provide more robust results. Additionally, there is a need for data from interventions and control groups to be reported transparently, this would allow data extraction, comparison and pooling of results from similar studies. Furthermore, it would enable researchers to determine the specific effective and ineffective components of both 20 mph 'zone' and 'limit' interventions.

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Appendix A. Supplementary data

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