Is Evidence in Practice?

Review of Driver and Cyclist Education Materials with Respect to Cycling Safety Evidence

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Countries with high cycling rates have national, school-based, mandatory cycling education programs; however, in North America, cycling education is diverse and disparate. The aim of this project was to understand what cycling safety content was delivered in Canadian jurisdictions and how training materials aligned with scientific evidence. Cycling safety literature was reviewed, and cycling education materials were compiled from drivers' licensing and cyclist education programs. The education materials were compared with the scientific evidence found in cycling safety literature to determine agreements, disagreements, or gaps. Fifty-six scientific articles focused on crash or injury risk, injury severity, or other safety outcomes and met the project's inclusion criteria. The evidence in these articles covered bicycling operations, visibility and safety gear, road characteristics, route types, and bicycle–motor vehicle interactions. Forty-eight training materials for cyclists, drivers, or both were gathered from 12 provincial and territorial driver's licensing jurisdictions, five municipalities, and seven advocacy organizations. Materials covered bicycle fit and maintenance, rules of the road, bicycle operations, visibility and safety gear, bicycle–motor vehicle interactions, route characteristics, and route types. Most education topics were supported by scientific evidence, except topics related to legislation or common sense. Evidence on motor vehicle passing distances conflicted with some educational material guidance about where to cycle on the road. A gap in the educational materials was the relative safety of different route infrastructure, important for route planning. This research illustrated the diversity of cycling education in Canada and revealed areas in which education materials could be modified to align with scientific evidence on safe cycling.

Cycling is a healthy activity (*1, 2*), but injury risk concerns many people and challenges the promotion of cycling in North America (*3*). Cycling in the United States and Canada carries a higher risk of injury or fatality than does driving per trip or per distance traveled (*4, 5*). Cycling is more dangerous in North America than it is in many northern European countries (*6*).

Education is one key component that differs between the countries that are safe and less safe for cycling (*7*). The education of cyclists, at a young age or as adults, can increase knowledge, competency, and confidence on the road (*8*). The education of drivers, either as individuals or as professional bus and truck drivers, can improve understanding of the vulnerabilities, behavior, and rules by which cyclists and drivers share road space (*8, 9*). Education is ever more important as new types of cycling-specific infrastructure are introduced in our cities (e.g., cycle tracks, bike boxes) with the goal to attract a wider segment of the population to cycling.

Between regions, diversity is great in the approach toward cycling education. In countries with high cycling modal shares or major investments in increased cycling, programs on cycling education often are institutionalized. For example, in the Netherlands, Denmark, and Germany, where in some cities one in three trips are made by bicycle, every child undergoes comprehensive training as part of the elementary school curriculum (*7*). In the United Kingdom, the Department for Transport provides £11 million annually to fund its Bikeability Program, which reaches more than 300,000 primary school students each year (*10*). In the United States and Canada, there is no mandatory national guideline for cyclist education, school-based or otherwise. The United States does have the federally funded Safe Routes to School Program to promote both walking and cycling to school, but it is offered in less than 7% of schools across the country, and participation is subject to parental interest (*11*). In Canada, most teens and adults learn about cycling safety through motor vehicle drivers' licensing materials (*12–22*). The content of these materials differs by jurisdiction but may include guidance about how drivers should behave around bicycles and, less frequently, about how cyclists should behave on the road. Cycling-specific safety education materials (e.g., pamphlets, websites) often are available through state or provincial authorities. Specialized cycling training programs, such as practical courses targeted to children, women, beginners, or experienced riders, also exist in many forms, and may be offered by local cycling associations, community associations, municipal governments, various service groups, or individual instructors.

Given the diversity of educational initiatives in North America, little is known about the cycling safety content that is being delivered. Moreover, no assessment has been made as to whether the content is aligned with the growing body of evidence on cycling safety from the disciplines of engineering, public health, and urban planning. The aim of the project reported here was to improve cycling safety training through a comparison of cycling education materials and research on cycling safety. This comparison was done through the completion of an inventory of cycling education materials from drivers' licensing and cyclist education programs across Canada. A review of the scientific literature on cycling safety was completed, and the content of the education materials was then compared with existing evidence to determine where materials agreed or disagreed, where safety messages existed that were not covered in the scientific literature, and where evidence might exist but was not used.

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Transportation Research Record: Journal of the Transportation Research Board, No. 2387, Transportation Research Board of the National Academies, Washington, D.C., 2013, pp. 35–45.
DOI: 10.3141/2387-05

METHODS

Cycling Safety Evidence Review

Search Strategy

A search was conducted with PubMed, Medline, and the Transportation Research Information Service and updated through January 2012. Combinations of the following keywords were used (with "wildcards," where appropriate, to capture variants on terms): bicycle, safety, injury, accident, crash, conflict, infrastructure, road, and intersection. Reference lists of all relevant papers, including review papers, were searched as a source of additional citations.

Inclusion and Exclusion Criteria

To be included, research articles had to investigate the relationship between a clearly defined metric of bicyclist safety (i.e., injury; injury severity; crash, collision, or fall; conflict) and either a riding practice (e.g., use of visible clothing, operation of bicycle, choice of route) or an environmental factor (e.g., grade, weather conditions). All research articles had to be in English. Articles were excluded if they were (*a*) studies that focused exclusively on helmet use; (*b*) studies of injuries or crashes that occurred in bicycle racing, off-road mountain biking, trick or trials riding, or play; (*c*) studies that examined only the personal characteristics of the bicyclists or motor vehicle drivers (e.g., age, sex, experience); (*d*) studies of injuries not related to a crash event (e.g., chronic injuries related to riding position); studies that examined gross numbers or types of injuries in a region for a given time period without either calculation rates (per exposure or riding time) or consideration of infrastructural determinants of those injuries; (*e*) studies that reported only subjective perceptions of safety or risk, whether by the lay public or experts; and (*f*) studies that did not contain original research.

All research articles identified by the search were screened for relevance with the use of the title, abstract, or both, by one of the authors of this paper. Selected articles were then reviewed in full for their fit with the inclusion and exclusion criteria. In any instance in which an article's relevance was unclear, one or two of this paper's other authors, or both, reviewed the article in full. The evidence in the selected articles was categorized according to safety topic and safety outcome.

Education Resources

Driver and cyclist education training materials were identified on the basis of a systematic search of provincial driver's licensing agencies, web searches, word of mouth, and cycling advocacy and education networks. The content of the educational materials was categorized by one author of this paper, and a subset was reviewed by another for verification.

Analysis

The database of topics covered in the educational materials was compared with the existing evidence from the literature review to identify the overlap between training materials and evidence, gaps in knowledge in the literature, or aspects of cycling safety covered in the literature but not translated into practice.

RESULTS

Scientific Evidence on Cycling Safety

More than 400 scientific articles potentially related to cycling injuries and crashes were identified. Fifty-six papers (*23–78*) met the study criteria (Table 1). Many studies were excluded because they were descriptive in nature only, they did not control for exposure to risk, or they did not make the comparisons necessary to draw safety-related conclusions. The final sample of articles came from around the world, including 27 from North America (*23–25, 29, 35, 36, 38, 39, 40, 42, 44–45, 48, 50, 51, 53–55, 61, 62, 65, 66, 68, 69, 71, 73*), 12 from Western Europe (*31–34, 41, 56–58, 60, 63, 64, 76*), seven from Australia and New Zealand (*28, 30, 43, 49, 70, 72, 77*), five from Britain (*37, 52, 59, 67, 74*), three from Asia (*47, 75, 78*), one from South America (*26*), and one from Eastern Europe (*27*). The articles covered three types of health outcomes: injury or crash risk, injury severity, and other safety information on topics that included conflict and visibility.

Cycling safety topics with substantial, consistent evidence were bicycling operations, visibility and safety equipment, road characteristics, route types, and bicycle–motor vehicle interactions. Table 2 presents the summary of the scientific evidence on cycling safety for these topics, and the agreement between studies on the same topic. Most studies concurred with respect to the direction of effect on injury and crash risk and injury severity. Topics about which there were some conflicting results were highlighted (e.g., bicycling operations, riding in opposite direction of motor vehicle traffic; route types, multiuse paths), but a detailed critique of the methodology involved was beyond the scope of this review.

On some topics, the conflicting results made it difficult to draw conclusions. One example was riding speed: two studies found an increased risk of crash for cyclists that rode rapidly (*26, 79*). (In one of these studies, cycling rapidly was coupled with other risky behaviors.) Still another study found reduced risk among cyclists that rode rapidly (*70*). The authors of this study suggested that this finding could have reflected the fact that more advanced and experienced cyclists rode faster than newer, less experienced cyclists. Another example had to do with children that rode on sidewalks: one study found a decreased risk of injury for children that rode on sidewalks and in playgrounds rather than on the street (*71*). Two other studies found, however, that their risk of injury increased (*28, 65*). One set of authors suggested the finding might have implied that experienced child cyclists rode on the road, while newer cyclists rode on the sidewalk (*65*). Three other topics whose study led to conflicting results were off-road and unpaved paths (*49, 53, 71*), intersections (*43, 45, 69, 73*), and curved road sections (*27, 44, 51*). A variety of possible explanations were offered for the differences in the results: the safety risk definition (e.g., of the route type, such as unpaved routes, which might group trails, paths, as well as bicycle-specific facilities), the cyclist population (e.g., inclusion of injuries to mountain bikers increased the risk estimates for off-road paths), the safety outcome considered, and finally, methodological differences, including a lack of consideration of risk exposure, especially in the case of the results on intersections. These topics whose study has produced conflicting evidence warrant further study to clarify the safety impacts.

Topics addressed only by individual studies are listed in Table 3. They included topics of emerging interest (e.g., road treatments such as bike boxes or colored lanes) that merit further study.

TABLE 1 Scientific Literature on Cycling Safety in Review

Reference	Date	Location	Study Population	Safety Outcome: Injury or Crash Risk	Safety Outcome: Injury Severity	Safety Outcome: Other	Safety Topic: Bicycling Operations[a]	Safety Topic: Visibility and Safety Gear	Safety Topic: Road Characteristics	Safety Topic: Route Types	Safety Topic: Bicycle–Motor Vehicle Interactions
Allen-Munley et al. (*23*)	2004	United States	314 bicycle crashes over 3 years	X	X		X			X	X
Aultman-Hall and Kaltenecker (*24*)	1999	Canada	1,196 bicycle commuters	X						X	
Aultman-Hall and Hall (*25*)	1998	Canada	1,604 bicycle commuters	X						X	
Bacchieri et al. (*26*)	2010	Brazil	1,133 male cyclists	X							
Bil et al. (*27*)	2010	Czech Republic	968 fatalities from 1995–2007	X	X		X	X	X		
Carlin et al. (*28*)	1995	Australia	109 children injured while riding and 118 controls	X						X	
Crocker et al. (*29*)	2010	United States	198 injured cyclists		X		X				
Cumming (*30*)	2011	Australia	Crashes from 2005–2009	X					X		
Daniels et al. (*31*)	2008	Netherlands	411 crashes from 1991–2001 for 91 roundabouts constructed 1994–2000	X					X		
De Brabander and Vereeck (*32*)	2007	Belgium	2,125 crashes at 95 roundabouts from 1991–2001	X	X				X		
de Waard et al. (*33*)	2010	Netherlands	24 cyclists on a 220-m path			X	X				
de Waard et al. (*34*)	2011	Netherlands	25 cyclists on a 220-m path			X	X				
Dill et al. (*35*)	2012	United States	Before-and-after observations at 10 bike boxes and two control sites			X					
Duthie et al. (*36*)	2010	United States	Observations at 48 sites			X				X	
Gilbert and McCarthy (*37*)	1994	Britain	178 fatalities from 1985–1992		X						X
Hagel et al. (*38*)	2007	Canada				X			X		
Haileyesus et al. (*39*)	2007	United States	62,267 cyclist–motor vehicle crashes from 2001–2004		X						X
Harris et al. (*40*)	2012	Canada	688 injury events	X			X		X	X	
Hels and Orozova-Bekkevold (*41*)	2007	Denmark	152 crashes at 88 roundabouts from 1999–2003	X					X		
Hunter et al. (*42*)	2005	United States	Before-and-after observations at 7 sites			X				X	
Johnson et al. (*43*)	2010	Australia	Observations from 128 h of cyclists footage			X					
Kim et al. (*44*)	2007	United States	2,934 crashes from 1997–2002		X		X	X	X		X
Klop and Khattak (*45*)	1999	United States	1,025 crashes from 1990–1993	X	X			X	X	X	
Li et al. (*46*)	2001	United States	124 seriously or fatal injuries and 324 controls		X		X				
Loo and Tsui (*47*)	2010	Hong Kong	4,985 crashes from 2005–2007		X					X	X
Lusk et al. (*48*)	2011	Canada	340 injuries from 1999–2008, 24-h cycle counts for 6 cycle tracks	X						X	
Meuleners et al. (*49*)	2007	Australia	151 crashes over 6 months		X					X	
Miranda-Moreno et al. (*50*)	2011	Canada	Crashes at 753 intersection over 9 years	X					X		X

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TABLE 1 *(continued)* **Scientific Literature on Cycling Safety in Review**

Reference	Date	Location	Study Population	Safety Outcome			Safety Topic				
				Injury or Crash Risk	Injury Severity	Other	Bicycling Operations[a]	Visibility and Safety Gear	Road Characteristics	Route Types	Bicycle–Motor Vehicle Interactions
Moore et al. (*51*)	2011	United States	10,029 crashes from 2002–2008		X		X		X		X
Morgan et al. (*52*)	2010	Britain	242 fatalities from 1996–2002		X						X
Moritz (*53*)	1998	United States	1,956 surveys	X						X	
Moritz (*54*)	1997	United States	2,374 surveys	X						X	
Nicaj et al. (*55*)	2009	United States	225 fatalities from 1996–2005	X	X		X			X	
Nygardhs et al. (*56*)	2010	Sweden	12 participants, 10-km route with 9 cycle crossings			X					
Olkkonen and Honkanen (*57*)	1990	Finland	140 non-fatally injured cyclists and 700 controls	X			X				
Ostrom et al. (*58*)	1993	Sweden	146 fatalities in 11 years		X						X
Parkin and Meyers (*59*)	2010	Britain	Video footage from 3 locations			X				X	
Rasanen and Summala (*60*)	1998	Finland	143 crashes	X			X				
Rivara et al. (*61*)	1997	United States	3,390 injured cyclists over 3 years		X						X
Rodgers (*62*)	1995	United States	841 and 917 fatalities over 1 year, 1,254 interviews with riders		X			X			
Sakshaug et al. (*63*)	2010	Sweden	53 h of observation at 2 roundabouts	X		X	X		X		
Schepers and den Brinker (*64*)	2011	Netherlands	1,142 single-bicycle crashes			X		X			
Senturia et al. (*65*)	1997	United States	47 injured child cyclists and 42 controls								
Spaite et al. (*66*)	1995	United States	350 injured cyclists		X		X				
Stone and Broughton (*67*)	2003	Britain	30,000 fatalities from 1990–1999		X				X		
Stutts and Hunter (*68*)	1999	United States	1,066 injured cyclists		X						X
Teschke et al. (*69*)	2012	Canada	690 injured cyclists	X					X	X	
Thornley et al. (*70*)	2008	New Zealand	2,469 cyclists	X				X			
Tinsworth et al. (*71*)	1994	United States	420 cyclists injuries, ~1,250 cycling households	X	X			X		X	
Turner et al. (*72*)	2011	Australia and New Zealand	102 intersections	X							
Wachtel and Lewiston (*73*)	1994	United States	314 bicycle–motor vehicle crashes from 1981–1990	X			X				
Walker (*74*)	2007	Britain	Video footage from 320 km of cycling		X	X				X	X
Wang et al. (*75*)	2009	Taiwan	324 bicycle-related head injuries from 2001–2002		X				X		X
Wanvik (*76*)	2009	Netherlands	762,835 injuries and 3,271,343 property-damage-only crashes, 1987–2006	X				X			
Wood et al. (*77*)	2010	Australia	24 participants, 1.8-km route with 2 cyclist locations			X			X		
Yan et al. (*78*)	2011	China	1,914 crashes from 2004–2007		X	X			X		X

NOTE: $n = 56$ articles; X = applicable; blank cell = not applicable.
[a]Bicycling operations includes cycling when intoxicated, cycling while using mobile devices or listening to music, or cycling behavior such as riding in the opposite direction of traffic.

TABLE 2 Summary of Topics with Consistent Scientific Evidence on Cycling Safety

Topic	Number of Papers	Conclusions: Injury or Crash Risk	Conclusions: Injury Severity	Conclusions: Other Safety Information	Agreement
Bicycling Operations					
Alcohol intoxication	7	Increased risk (*55, 57*)	Increased severity (*29, 44, 46, 51, 66*)		All studies agree
Talking or texting on a mobile phone, listening to music while cycling	2			Reduces visual and auditory perception (*33*) Reduces speeds (*34*)	Both studies concur, but both are small studies by the same person
Riding in opposite direction of motor vehicle traffic	7	Increased risk (*40, 60, 63, 73*)	Increased severity (*23, 27, 44*)		One study does not concur, but did find head-on collisions to be the most severe
Visibility and Safety Equipment					
Dark, unlit conditions	9	Increased risk (*71, 76*)	Increased severity (*27, 44, 45, 62, 71, 78*)	(*64*)	All studies agree
Foggy and inclement weather conditions	2		Increased severity (*44, 45*)		All studies agree
Wearing fluorescent clothing and reflectors	4	Decreased risk (*70*)	Decreased severity (*75*)	Reflective clothing and reflectors increase visibility at nighttime but fluorescent clothing does not (*77*) Bright (yellow, red, and orange) and white clothing increased cyclist visibility in daytime (*79*)	All studies agree
Road Characteristics					
Grades	4 (3 studies)	Increased risk (*40, 69*)	Increased severity (*23, 45*)		All studies agree
Medians and divided roadways	2		Decreased severity (*44, 78*)		All studies agree
Roundabouts and traffic circles	6	Increased risk (*30–32, 40, 41*)	Increased severity (*29*)	Roundabouts with separated cycling facilities are safer than those without (*63*)	All studies agree
High motor vehicle speed limits–speeds	9	Increased risk (*40, 41*)	Increased severity (*27, 44, 45, 51, 67, 75, 78*)		All studies agree
Traffic volumes	4	Increased risk (*40, 50*)	Decreased severity (*23, 45*)		All studies agree
Route Types					
Cycle tracks	4 (3 studies)	Decreased risk (*40, 48, 69*)	Decreased severity (*47*)		All studies agree
Bike lanes	4 (3 studies)	Decreased risk (*40, 53, 54, 69*)			All studies agree
Multiuse paths	5 (4 studies)	Increased risk (*24, 25, 40, 53, 69*)			4 of 5 analyses find increased risk on multiuse paths as compared with streets
Signed bike route	4 (3 studies)	Decreased risk (*40, 53, 54, 69*)			All studies agree
Sidewalks	7 (6 studies)	Increased risk (*24, 25, 40, 53, 54, 69, 73*)			All studies agree
Minor streets without bike facilities	5 (4 studies)	Decreased risk (*40, 53, 54, 69*)	Decreased severity (*49*)		All studies agree
Major streets without bike facilities	8 (7 studies)	Increased risk (*28, 40, 53, 54, 69, 71*)	Increased severity (*49, 55*)		All studies agree
Highways	2		Increased severity (*23, 49*)		All studies agree

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TABLE 2 *(continued)* **Summary of Topics with Consistent Scientific Evidence on Cycling Safety**

Topic	Number of Papers	Conclusions: Injury or Crash Risk	Injury Severity	Other Safety Information	Agreement
Bicycle–Motor Vehicle Interactions					
Passing distance	6	Increased risk (*23*)	Increased severity (*45*)	Motorists pass closer to cyclists on higher speed and wider roads (*59*) The farther cyclists ride from the curb the less space they are given when passed (*36, 74*) Motorists pass closer to cyclists when a bike lane is provided (*59*)	All studies agree
Motor vehicle involvement in crashes	4		Increased severity (*39, 47, 61, 68*)		All studies agree
Heavy vehicles	10	Increased risk (*50*)	Increased severity (*23, 37, 44, 51, 52, 58, 75, 78*)	Heavy vehicles pass closer to cyclists (*74*)	All studies agree

TABLE 3 Safety Topics Covered by Only One Study to Date

Safety Topic	Finding
Behavior	
Risky behavior (*26*)	Cyclists who engage in risky behaviors (cycling rapidly, zigzagging through traffic, and riding after ingesting alcohol) had an RR of being in a crash of 1.56.
Cyclists failing to give the right-of-way to cars (*28*)	Cyclists failing to give right-of-way to cars account for 63% of fatal crashes where the cyclist is at fault, with an OR for all crashes of 3.28 compared with the most common scenario: the motorist at fault and denies the right-of-way.
Looking away from road (*64*)	OR 4.21 for looking at the side of the road and 3.87 for looking behind, compared with all other single bicycle crashes, among bicycle crashes related to visual design of the site (hitting the curb, going off the road, etc).
Visibility at crossings (*56*)	At night, cyclist dummies waiting at the edge of the road as if to cross were visible at a significantly longer distance than cycle crossings, and cycle crossings (though not the cyclist dummies) were significantly less visible in wet conditions.
Infrastructure	
Bike boxes (*35*)	Bike boxes decreased bicycle–motor vehicle and bicycle–pedestrian conflicts.
Colored cycle lanes (*72*)	Addition of colored cycle lanes to a site decreased crashes by 39%.
Separated left-turn lanes (*72*)	Sites with exclusive left-turn lanes were much safer for cyclists than those with a shared through and left-turn lane.
Recently paved roads (*23*)	Recently paved roads were associated with decreased injury severity.
Train or streetcar tracks[a] (*40, 69*)	The presence of streetcar or train tracks was associated with increased injury risk, OR = 4.15. The presence of streetcar or train tracks was associated with increased injury risk, OR = 3.04.
Construction[a] (*40, 69*)	Construction on the route was associated with increased injury risk, OR = 2.67. Construction on the route was associated with increased injury risk, OR = 1.93.

NOTE: RR = relative risk; OR = odds ratio.
[a]Multiple papers from same study.

Education Materials

Training materials with information for cyclists, drivers, or both, were gathered from 12 provincial and territorial driver's licensing jurisdictions, five municipalities, and seven cycling advocacy or green transportation organizations. In addition to driver's handbooks, two provincial insurance companies and two provincial transportation departments provided detailed cycling safety guides. Forty-eight resource materials were identified: 16 from cycling advocacy groups (*80–95*), 11 from provincial or territorial departments of transportations (*12–22*), 10 from provincial insurance companies (*96–105*), seven from municipalities (*106–112*), three from an individual trainer (*113–115*), and one from a green transportation organization (*116*). Three (*16, 98, 101*) of the materials were specifically oriented to young cyclists. The scope of materials ranged from single-paged information sheets to comprehensive booklets.

Of the materials gathered, 18 of the 48 included information for drivers on how to share the road with cyclists (*12, 13, 15, 17, 19, 20, 22, 80, 83, 97, 99, 100, 102–105, 107, 110*). Guidance focused on interactions at intersections (e.g., drivers should check for cyclists to the right before they make a right turn, or they should look for oncoming cyclists before they make a left turn) and along the roads (e.g., drivers should check for cyclists when they open vehicle doors or pull out from street parking, they should make eye contact with cyclists, they should leave ample room when they pass cyclists).

The materials had a broader spectrum of messages for cyclists, with seven overarching topics: bicycle fit and maintenance, rules of the road, bicycle operation, visibility and safety gear, bicycle–motor vehicle interactions, route characteristics, and route types (the last five of these topics corresponded to the evidence topics). Table 4 provides examples of items included in educational materials that fit within these overarching topics and identifies whether individual items were supported by scientific evidence.

Comparison of Materials and Evidence

Some overarching topics had no supporting evidence. Bicycle fit and maintenance and the rules of the road were both commonly addressed in the education materials. The former topic was covered by 20 of

TABLE 4 Comparison of Cycling Education Training Materials and Scientific Evidence

Overarching Topic	Education Items Supported by Evidence (*n*)	Education Items Not Covered by Evidence (*n*)	Gaps in Education Materials and Conflicts Between Evidence and Education Items (*n*)
Bicycle fit and maintenance	na	Bike and brakes are in good condition (17). Bike is correct size (12). Tires are fully inflated (10). Drive train is clean (7).	na
Rules of the road	na	Bike is legally considered a vehicle, obey laws, signs, signals (27). Ride single file except when passing (11). Yield to pedestrians (6). Do not pass on the right (5). Yield to new lane traffic (3). Bike lane, sharrows, or traffic circle instructions (1). Streetcar and school bus stop distances (1).	na
Bicycling operations	Pay attention and keep eyes on the road (3). Do not use a mobile device (talking or texting) while riding (3). Do not ride while intoxicated (2).	Use hand signals when changing lanes, turning, or stopping (20). Shoulder check when changing lanes or turning (18). Do not carry more passengers than bicycle was designed for (11). Anticipate unforeseen events (8). Detailed left-turning instructions (8). Move out of right-turn lanes if not turning (6). Stop and look before entering the street (5). Keep control of your bike (4). Arrange baggage to keep bike stable (3).	Gap: evidence indicates that listening to music while cycling reduces cyclists' stability and perception.
Visibility and safety gear	Wear a helmet (25). Use lights after dark (29). Wear reflectors and fluorescent, bright, or white clothing (26).	Bike should have a bell or horn (17). Use a rearview mirror (4). Flashing lights are safer (3). Attach a pennant to bicycle to force vehicles to leave more room (2). Wear gloves and safety glasses (2).	Gap: evidence indicates that foggy conditions increase injury severity.
Bicycle–motor vehicle interactions	Ride in direction of traffic (16). Be extra cautious of heavy vehicles turning right (3). Yield to cross traffic (3). Stay away from large vehicles (2).	Ride in a straight line and stay in motorist's field of vision (21). Take the entire lane if it is safest (14). Stay behind right-turning cars at intersections (11). Beware of parked cars pulling out or opening doors (10). Look for cars pulling out of driveways and side streets (10). Look for cars turning left across your path (5). Make eye contact with drivers (4). Ride far enough behind so that the driver can see you in his side mirror (2).	Conflict: training materials recommend riding approximately 1 m (3.3 ft) away from curb or parked cars (17), and evidence indicates vehicles pass closer to cyclists riding farther from the curb.
Route characteristics	Cross railroad tracks at right angle (6).	Be aware of road hazards: gravel, holes, bumps, and objects (9). Be aware of weather conditions; brakes work less well when wet (8). Ride slowly; brake lightly in snow and ice (3).	Gap: evidence indicates that roundabouts present an elevated injury risk for cyclists.
Route types	Do not ride on sidewalks (14). Avoid riding on major roads and highways (1).	na	Gaps: evidence indicates that bike-specific routes decrease crash risk and injury severity; evidence indicates that routes separated from traffic or with low traffic volumes decrease crash risk and injury severity.

NOTE: Number of cycling education resource materials identified = 48; (*n*) = number of materials that included item; na = not applicable.

the materials, and the latter by 48. These topics may be governed by common sense and legislation, instead of safety evidence.

Within the other overarching topics, some items had corresponding evidence and others did not (Table 4). For example, under bicycle–motor vehicle interactions, the project review found evidence that supported the practice of riding in the direction of traffic, which was an item mentioned in 16 of the 48 educational materials [Table 2 (*40, 60, 63, 73*)]. No specific literature was found, however, to support actions taken by cyclists such as to ride in a straight line, take the entire lane, and ride far enough behind to be seen in a vehicle's side mirror. For the safety gear items (within visibility and safety gear), no evidence linked gloves or safety glasses to cycling safety. A large body of evidence linked helmet use to head injury mitigation, which has had substantial attention (*117, 118*). This topic was excluded from the current review to focus on safety messaging beyond helmets.

The final column of Table 4 identifies gaps in the educational materials, for which evidence exists but has not been incorporated into training, as well as items for which the education message and evidence are in conflict. The one conflict was with respect to the position on the road. Although 17 of the 48 materials recommended that cyclists ride 1 m (3.3 ft) from the curb, this recommendation did not align with evidence that passing distances were smaller when cyclists were farther from the curb. Several gaps were found with respect to the translation of the evidence into training materials. Items for which there was evidence but no mention in the education materials included the increased risk associated with roundabouts; decreased risk associated with cycling-specific facilities and routes with low traffic volumes; increased risk associated with foggy conditions and not only rain and darkness; and decreased stability and perception of cyclists that listened to music while they rode.

DISCUSSION OF RESULTS

This research developed an inventory of cycling education materials across Canada and reviewed scientific evidence related to cycling safety to determine how the safety-related messages used in practice reflected the state of knowledge. This research identified similarities and differences between education materials, areas in which education materials were missing information supported by scientific evidence, as well as materials that included contradicted evidence or that made unsubstantiated claims.

Despite the broad scope of the training materials gathered, a good degree of overlap was found in the topics covered. A report that will provide an item-by-item comparison is in preparation to share with organizations that provide cycling and driver training. It is a first step toward more standardized training materials in emulation of the approach taken in the Netherlands, Denmark, and the United Kingdom. The comparison with existing evidence provided is a basis to recommend evidence-based changes to the materials.

This review was a scoping one of the available evidence on cycling safety to inform educational training materials. Agreement was sought among research topics (Table 2) and the identification of topics for which there was little evidence (Table 3 and Table 4). Agreement was one consideration, but methodology and quality also were important. The literature contains rich discussions of the limitations of cycling safety research, which addresses the challenges of study design (*119*), route type characterization (*120*), adjustment for exposure (*119*), and underreporting of injury events (*121, 122*), among other concerns. Health, planning, and engineering disciplines all undertake cycling safety research, and each applies its respective methodologies and statistical methods. The research included here was heterogeneous, and the breadth of cycling safety topics was wide. As a result, the focus was on overall agreement, gaps, and conflicts. Future papers may elaborate on the relative quality of each research effort on a given topic.

A major focus in the literature was on the relative risk of different route types, yet guidance on route planning essentially was absent from educational materials. Only one training material explicitly recommended that cyclists stay away from busy roads and highways (*101*). Yet there is substantial evidence that major streets and highways without bicycle infrastructure are associated with increased injury risk, injury severity, or both (*28, 40, 53, 54, 69, 71*) and that cycling-specific facilities decrease risks (*27, 34, 35, 41, 42, 57*). More explicit direction on the relative safety of different route types could help guide cyclists on how to choose safer routes in cases in which such choices were an option.

The educational information was in conflict with the existing scientific evidence with respect to where to ride on the road. In the literature that looked at the distance left by motor vehicles when they passed a cyclist, decreased passing distance was associated with cyclists that rode far from the curb [including cyclists in bike lanes (*36, 74*)]. Cars also were found to pass closer on wider roads, despite their having more room (*59*). However, nearly a third of the education materials advised cyclists to ride 1 m (3.3 ft) from the curb, which, according to the evidence, might reduce motor vehicle passing distances. This item was one that could be amended in cycling training materials to concur with the state of knowledge.

Not all of the topics covered by the education materials were supported by the scientific evidence. Many fell under the category of common sense, and instructed cyclists on the rules of the road and the potential hazards they might encounter. Indeed, the types of items included in education materials were of a different tenor, and many addressed topics that would be difficult to study scientifically (e.g., cyclist eye contact with drivers, bicycle maintenance), although they may be important. Of greater concern were the unsubstantiated claims in some of the educational materials in which statistics were presented as facts but sources were not cited, which were potentially misleading. For example, one resource included a breakdown of common collision types: "Falls - 50% of collisions, Bike–Bike - 17% of all collisions, Car–Bike - 17% of all collisions, Bike–Dog - 8% of all collisions." The data source was not included. More important, this type of simple breakdown without denominators can be misleading and imply that dogs present half the risk of cars. Several resources stated that most bicycle crashes occurred at intersections (*81, 86, 116*) without consideration of whether or not the data included all crashes or only those with motor vehicles. Most scientific literature about intersection risk was not methodologically rigorous (i.e., did not account for cyclist exposure to risk at intersections compared with their exposure to risk elsewhere), so no conclusions could be drawn about the relative risks of intersections.

Many education materials cited facts about who was most at fault in crashes. Such statements were misleading and could promote an us-versus-them attitude between cyclists and motorists [e.g., "Adults are most likely injured by motorist error" and in the same source "Only 4% of collisions are motorist error (0.8% of all collisions)"]. Presentation of such statements as facts is not appropriate, not only because the statements contradict one another but because the context is unclear. Do these statements refer to all crashes, or just bicycle–motor vehicle crashes? Do they apply only to roadways, or to off-street paths as well? Such statistics also do not account for the number of times a motorist made an error near a cyclist that did not result in a crash. To ignore cyclist exposure leads to scientifically uninterpretable information that can confuse or, worse, misdirect education about cycling safety.

This review focused on the overlap between training materials and evidence. The premise was that more knowledge about safe cycling will translate into safer cycling behavior, although it was acknowledged that behavioral change was complex. Subsequent work may evaluate the effectiveness of bicycle training programs on cycling activity or safety outcomes. Aside from studies of programs that promote helmet use (*117*), few rigorous evaluations have linked cycling safety training to increased cycling (*123*) and to increased knowledge (*124*), nor have they linked greater knowledge about road safety to lower risk of injury (*125*). However, evaluation efforts are challenging, especially in the North American paradigm of distributed and diverse education training. In terms of implications for cycling training curriculum development, a step to follow on from this study would be to compare the educational materials for Canada, compiled here, with those used in national training programs elsewhere.

CONCLUSIONS

Overall, the research found that many of the safety-related principles covered by cycling education materials in Canada were supported by scientific evidence. However, some topics supported by evidence were not taught or emphasized, especially as they related to which route types minimized cyclist risk of injury. A number of education topics were simply not addressed in the literature but would provide useful information to cyclists about the rules of the road and bicycle maintenance.

Uncited, ambiguous facts in education materials were a problem. A recommendation for practice is that all sources of statistics in education materials be cited, so that trainers and cyclists can refer to the original material and examine the context in which it is presented. Statistics cited in education materials should be appraised to ensure that they measure risk or relative risk, rather than merely present simple, descriptive data, so that trainees do not receive a misleading impression of the causes of crashes or injuries.

The cycling safety literature cited in this paper could be used as a source for those that created and refined cycling education. The documentation provides a platform for updates as relevant bicycling safety research is published over time.

ACKNOWLEDGMENT

This work was funded by the Canadian Institutes for Health Research.

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The Bicycle Transportation Committee peer-reviewed this paper.