Risk of injury for bicycling on cycle tracks versus in the street

Anne C Lusk,1 Peter G Furth,2 Patrick Morency,3,4 Luis F Miranda-Moreno,5 Walter C Willett,1,6 Jack T Dennerlein7,8

ABSTRACT
Most individuals prefer bicycling separated from motor traffic. However, cycle tracks (physically separated bicycle-exclusive paths along roads, as found in The Netherlands) are discouraged in the USA by engineering guidance that suggests that facilities such as cycle tracks are more dangerous than the street. The objective of this study conducted in Montreal (with a longstanding network of cycle tracks) was to compare bicyclist injury rates on cycle tracks versus in the street. For six cycle tracks and comparable reference streets, vehicle/bicycle crashes and health record injury counts were obtained and use counts conducted. The relative risk (RR) of injury on cycle tracks, compared with reference streets, was determined. Overall, 2.5 times as many cyclists rode on cycle tracks compared with reference streets and there were 8.5 injuries and 10.5 crashes per million bicycle-kilometres. The RR of injury on cycle tracks was 0.72 (95% CI 0.60 to 0.85) compared with bicycling in reference streets. These data suggest that the injury risk of bicycling on cycle tracks is less than bicycling in the street. The construction of cycle tracks should not be discouraged.

Bicycling could address obesity, cancer, stroke, diabetes, asthma, mortality and pollution;1 however, the bicycling environment is a limiting factor. The predominant bicycle facilities in The Netherlands and Denmark are cycle tracks, or bicycle paths along streets that are physically separated from motor traffic, bicycle-exclusive and with a parallel sidewalk.5 Due to the separation from vehicles afforded by 29,000 km of cycle tracks in The Netherlands plus other initiatives,4 27% of Dutch trips are by bicycle, 55% are women, and the bicyclist injury rate is 0.14 injured/million km.5 In the USA, 0.5% of commuters bicycle to work, only 24% of adult cyclists are women,6 and the injury rate of bicyclists is at least 26 times greater than in The Netherlands.5 The chief obstacle to bicycling, especially for women,7 children8 and seniors9 is perceived danger of vehicular traffic. This perceived danger from cars appears to be real,10 as corroborated by survey participants who prefer cycle tracks over roads.11

Cycle track construction has been hampered in the USA by engineering guidance in the American Association of State Highway and Transportation Officials (AASHTO) ‘Guide for the development of bicycle facilities’12 which cautions against building two-way paths along, but physically separated from, a parallel road. AASHTO states that sidewalk bikeways are unsafe and implies the same about shared-use paths parallel to roads, listing numerous safety concerns and permitting their use only in special situations. Cycle tracks, which can be one or two-way and resemble shared-use paths, are not mentioned in the AASHTO bike guide. A longstanding, and yet not rigorously proved, philosophy in the USA has suggested instead that ‘bicyclists fare best when they behave as, and are treated as, operators of vehicles.’13 The details about cycle tracks in the Dutch bicycle design manual CROW14 and crash rate comparisons between the USA and The Netherlands5 have been dismissed by vehicular cycling proponents,14 with arguments of non-transferability to the American environment. Cycle tracks have been controversial, especially due to conflicting studies with warnings of increased crash rates.15 The warnings, which in the USA result in striped bike lanes but not cycle tracks, come without any substantial study of the safety of North American cycle tracks. Using existing crash and injury data from Montreal, Canada, a city with a network of cycle tracks in use for more than 20 years, this study compared bicyclists’ injury and crash rates with published data and bicyclists’ injury rates on cycle tracks versus in the street.

METHODS
We studied six cycle tracks in Montreal that are two-way on one side of the street. Each cycle track was compared with one or two reference streets without bicycle facilities that were considered alternative bicycling routes. One reference street was a continuation of the street with the cycle track; the remaining streets were parallel to the cycle track with the same cross streets as endpoints and, therefore, subject to approximately the same intersection frequency and cross traffic as the cycle track.

Injury and vehicle/bicycle crash rates per bicycle-kilometre
The injury and crash rates for each cycle track were determined from the emergency medical response (EMR) database16 and police-recorded vehicle/bicycle crashes and estimated on the cycle tracks per bicycle-km. Automated 24-h bicycle counts on Montreal cycle tracks are available for selected years, with 20–64 days in each sample from May to September. We used linear interpolation between the 2000 and 2008 samples to determine average daily use for the date ranges of the injury and crash counts. Average daily use was converted to annual use by multiplying by 200 ‘effective days’ in the 1 April to 15 November bicycling season (when seasonal cycle tracks are open), recognising that

Correspondence to
Dr Anne Lusk, Harvard School of Public Health, 665 Huntington Avenue, Building II, Room 314, Boston, MA 02115, USA; annelusk@hsph.harvard.edu

Accepted 1 December 2010
Published Online First
9 February 2011

This paper is freely available online under the BMJ Journals unlocked scheme, see http://injuryprevention.bmj.com/site/about/unlocked.shtml

1Department of Nutrition, Harvard School of Public Health, Boston, MA USA
2Department of Civil and Environmental Engineering, Northeastern University, Boston, MA USA
3Direction de santé publique de Montréal, Montréal, Québec, Canada
4 Département de Médecine Sociale et Préventive, Université de Montréal, Montréal, Québec, Canada
5Department of Civil Engineering and Applied Mechanics, McGill University, Montréal, Québec, Canada
6Department of Epidemiology, Harvard School of Public Health, Boston, MA, USA
7Department of Environmental Health, Harvard School of Public Health, Boston, MA, USA
8Department of Orthopaedic Surgery, Brigham and Women’s Hospital, Harvard Medical School, Boston, MA, USA

doi:10.1136/ip.2010.028696
RESULTS

All six cycle tracks were two-way on one side of the street and separated from traffic, as mixed, medians, parking lanes, or delineator posts. There were 8.5 and 10.5 crashes per million bicycle-km on the Maisonneuve and Brébeuf cycle tracks, respectively, and 22.5 crashes per million bicycle-km on the reference street. MVO injury counts are considered a surrogate for injury counts by that fraction. There were 10.5 injuries and 22.5 crashes per million bicycle-km on the Maisonneuve and Brébeuf cycle tracks, respectively, and 24.0 injuries and 37.0 crashes per million bicycle-km on the reference street. MVO injury counts are considered a surrogate for injury counts by that fraction.

A historical perspective of past annual data suggests that the seasonal cycle tracks are utilized for 7.5 months of the year. Demand is lower in April, October and November and, therefore, bicycle volume for a year is assumed to be 200 times the daily volume. Estimates of the fraction of the total bicycle use trends to be less in April, October and November than in the sampled months. Use estimates and the fraction of the data from police records overlap strongly, the injury data have been shown to be more exhaustive, and the injury data have been used as input. Although the data from police records overlap strongly, the injury data have been used as input.

The RR of the cycle track compared with the reference street was estimated using bicyclist counts and injuries from the EMR database. The RR of the cycle track compared with the reference street was estimated using bicyclist counts and injuries from the EMR database.

The RR of the cycle track compared with the reference street was estimated using bicyclist counts and injuries from the EMR database. The RR of the cycle track compared with the reference street was estimated using bicyclist counts and injuries from the EMR database.

**Relative Risk (RR) of injury for cycle tracks**

The Relative Risk (RR) of injury for cycle tracks was calculated using bicyclist counts and injuries from the EMR database. The RR of the cycle track compared with the reference street was estimated using bicyclist counts and injuries from the EMR database. The RR of the cycle track compared with the reference street was estimated using bicyclist counts and injuries from the EMR database.

**Injury Prevention**

Table 1 Injury and vehicle/bicycle crash rates for cycle tracks in Montreal, Quebec*

<table>
<thead>
<tr>
<th>Cycle track</th>
<th>Configuration</th>
<th>Separation</th>
<th>Length (km)</th>
<th>Length factor†</th>
<th>Cyclists/day, 1999–2008 ‡</th>
<th>Bike-km/year (millions) §</th>
<th>Injuries/year † †</th>
<th>Crashes/year † †</th>
<th>Injuries per million bike-km</th>
<th>Crashes per million bike-km</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Brébeuf (seasonal)</td>
<td>2-Way, 1 side of one-way street,</td>
<td>Delineator posts and parking lane</td>
<td>1.0</td>
<td>0.9</td>
<td>5316</td>
<td>0.96</td>
<td>3.8</td>
<td>1.8</td>
<td>4.1</td>
<td>1.9</td>
</tr>
<tr>
<td>2. Rachel</td>
<td>2-Way, 1 side of two-way street,</td>
<td>Raised median, delineator posts,</td>
<td>3.5</td>
<td>0.6</td>
<td>2581</td>
<td>1.08</td>
<td>12.6</td>
<td>17.0</td>
<td>11.6</td>
<td>15.7</td>
</tr>
<tr>
<td>3. Berri</td>
<td>2-Way, 1 side of two-way street,</td>
<td>Raised median, delineator posts,</td>
<td>1.4</td>
<td>0.8</td>
<td>2778</td>
<td>0.62</td>
<td>7.8</td>
<td>10.2</td>
<td>12.5</td>
<td>16.4</td>
</tr>
<tr>
<td>4. Maisonneuve, w. island (</td>
<td>2-Way, 1 side of one-way street,</td>
<td>Delineator posts</td>
<td>1.9</td>
<td>0.9</td>
<td>2379</td>
<td>0.81</td>
<td>1.9</td>
<td>2.6</td>
<td>2.3</td>
<td>3.2</td>
</tr>
<tr>
<td>5. Chr Colombe (seasonal)</td>
<td>2-Way, 1 side of two-way street,</td>
<td>Curb and (part) planting strip</td>
<td>3.7</td>
<td>0.7</td>
<td>921</td>
<td>0.48</td>
<td>6.7</td>
<td>9.2</td>
<td>14.1</td>
<td>19.3</td>
</tr>
<tr>
<td>6. René-Lévesque</td>
<td>2-Way, 1 side of two-way street,</td>
<td>Raised median, delineator posts,</td>
<td>1.3</td>
<td>0.8</td>
<td>1108</td>
<td>0.23</td>
<td>2.8</td>
<td>3.2</td>
<td>12.3</td>
<td>13.9</td>
</tr>
<tr>
<td>All</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Whole segments of the cycle track were studied and not just intersections.
†Length of the section studied, which may be less than the entire cycle track length for comparability with reference streets.
‡Fraction of the study section’s length ridden by a typical rider.
§Average for the May to September period over the period 1999–2008.
‡Year is the 7.5 month period (1 April to 15 November) when the seasonal cycle tracks are open.
**Demand is lower in April, October and November, and therefore, bicycle volume for a year is assumed to be 200 times the daily volume.
††Injuries (data source — emergency medical response) between 1 April and 15 November for the period 1 April 1999 to 31 July 2008 divided by 9.53.
‡‡Bicycle–motor vehicle crashes (data source — police reports) between 1 April and 15 November 2002–6, divided by 5.
Table 2 RR of injury for cycle tracks compared to similar on-street routes for Montreal, Quebec*

<table>
<thead>
<tr>
<th>Cycle track†</th>
<th>Reference street‡</th>
<th>Limiting cross streets</th>
<th>Length (km)</th>
<th>2-h bike count</th>
<th>EMR-reported injuries§</th>
<th>Reference street</th>
<th>2-h bike count</th>
<th>EMR-reported injuries§</th>
<th>RR (95% CI)¶</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Brebeuf</td>
<td>St Denis (N)</td>
<td>Rachel — Laurier</td>
<td>1.0</td>
<td>1193</td>
<td>37</td>
<td>437</td>
<td>32</td>
<td>0.42 (0.26 to 0.68)</td>
<td></td>
</tr>
<tr>
<td>2. Rachel</td>
<td>Mont Royal</td>
<td>St Urbain — Marquette</td>
<td>3.5</td>
<td>990</td>
<td>120</td>
<td>613</td>
<td>63</td>
<td>1.18 (0.87 to 1.60)</td>
<td></td>
</tr>
<tr>
<td>3. Berri</td>
<td>St Denis (S)</td>
<td>Cherrier — Viger</td>
<td>1.4</td>
<td>763</td>
<td>74</td>
<td>134</td>
<td>27</td>
<td>0.48 (0.31 to 0.75)</td>
<td></td>
</tr>
<tr>
<td>4. Maisonneuve</td>
<td>Both</td>
<td>Claremont — Wood</td>
<td>1.9</td>
<td>547</td>
<td>18</td>
<td>176**</td>
<td>18</td>
<td>0.32 (0.17 to 0.62)</td>
<td></td>
</tr>
<tr>
<td>5. Christophe Colomb</td>
<td>Both</td>
<td>Gouin — Jarry</td>
<td>3.7</td>
<td>407</td>
<td>64</td>
<td>122</td>
<td>19</td>
<td>1.01 (0.61 to 1.68)</td>
<td></td>
</tr>
<tr>
<td>6. Rene Levesque</td>
<td>Sherbrooke (E)</td>
<td>Lorimer — St Hubert</td>
<td>1.3</td>
<td>109</td>
<td>27</td>
<td>130</td>
<td>32</td>
<td>1.01 (0.60 to 1.68)</td>
<td></td>
</tr>
<tr>
<td>All</td>
<td></td>
<td></td>
<td>15.1</td>
<td>4009</td>
<td>340</td>
<td>1612</td>
<td>191</td>
<td>0.72 (0.60 to 0.85)</td>
<td></td>
</tr>
</tbody>
</table>

*Statistically significant comparisons are shown in bold.
†All cycle tracks are two-way on one side of the street.
‡An on-street bike route on a parallel street in close proximity of the cycle track.
§Injuries recorded by emergency medical response (EMR) services between 1 April 1999 and 31 July 2008 for the season 1 April to 15 November.
¶95%CI calculated using the variance of log(RR) based on a Poisson distribution.

Compared with bicycling on a reference street, the overall RR of injury on a cycle track was 0.72 (95% CI 0.60 to 0.85); thus, these cycle tracks had a 28% lower injury rate. Three of the cycle tracks exhibited RR less than 0.5, and none showed a significantly greater risk than its reference street. Overall, 2.5 times as many cyclists used the cycle tracks compared with the reference streets (table 2).

The relative danger from vehicular traffic of the cycle tracks compared with their reference streets was close to 1.0 overall, but with a wide range (table 3). Not surprisingly, the Brebeuf and Maisonneuve cycle tracks with lowest crash rate and relative injury risk (tables 1 and 2) also had the lowest relative danger from vehicular traffic (table 3). Yet even for the four cycle tracks on streets with vehicular traffic danger similar to or greater than its reference street, the cycle tracks still had less or a similar risk of injury.

DISCUSSION

Contrary to AASHTO’s safety cautions about road-parallel paths and its exclusion of cycle tracks, our results suggest that two-way cycle tracks on one side of the road have either lower or similar injury rates compared with bicycling in the street without bicycle provisions. This lowered risk is also in spite of the less-than-ideal design of the Montreal cycle tracks, such as lacking parking setbacks at intersections, a recommended practice.18 While the goal of this study was to consider both one and two-way cycle tracks, all of the Montreal cycle tracks were two-way with half the bicyclists riding in a direction opposite to that of the closest vehicular traffic, a practice not favoured by AASHTO. Although the Montreal cycle tracks were two-way, they had lower or similar risk compared with the road. The Dutch CROW bicycle guidelines suggest that one-way cycle tracks are even safer.3 The crash rate for Montreal’s cycle tracks (10.5 crashes per million bicycle-km) is low compared with the few and inconsistent crash rates in the literature. When calculated to include only vehicle/bicycle crashes, these rates range from 3.75 to 5419 in the USA and from 4620 to 6721 in Canada. The injury rate (8.5 injuries per million bicycle-km) lacks comparable data in the literature, partly because few communities have accessible bicycle-incident ambulance records. Although the Brebeuf and Maisonneuve cycle tracks were safer, the sample of six cycle

Table 3 Relative danger from vehicular traffic*

<table>
<thead>
<tr>
<th>Cycle track</th>
<th>Reference street</th>
<th>MVO injuries†</th>
<th>Cycle track</th>
<th>Reference street</th>
<th>Relative traffic danger of cycle track (95% CI)¶</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Brebeuf</td>
<td>St Denis (N)</td>
<td>8</td>
<td>90</td>
<td>0.09 (0.04 to 0.18)</td>
<td></td>
</tr>
<tr>
<td>2. Rachel</td>
<td>Mont Royal</td>
<td>86</td>
<td>69</td>
<td>1.25 (0.91 to 1.73)</td>
<td></td>
</tr>
<tr>
<td>3. Berri</td>
<td>St Denis (S)</td>
<td>127</td>
<td>116</td>
<td>1.09 (0.85 to 1.41)</td>
<td></td>
</tr>
<tr>
<td>4. Maisonneuve</td>
<td>Both</td>
<td>13</td>
<td>59§</td>
<td>0.22 (0.12 to 0.40)</td>
<td></td>
</tr>
<tr>
<td>5. Christophe Colomb</td>
<td>Both</td>
<td>367</td>
<td>217§</td>
<td>1.69 (1.43 to 2.00)</td>
<td></td>
</tr>
<tr>
<td>6. Rene Levesque</td>
<td>Sherbrooke (E)</td>
<td>196</td>
<td>205</td>
<td>0.96 (0.79 to 1.16)</td>
<td></td>
</tr>
<tr>
<td>All</td>
<td>Sherbrooke (E)</td>
<td>797</td>
<td>756</td>
<td>1.05 (0.95 to 1.16)</td>
<td></td>
</tr>
</tbody>
</table>

*Statistically significant comparisons are shown in bold.
†Injuries to motor vehicle occupants recorded by emergency medical response (EMR) services between 1 January 1999 and 31 July 2008.
¶95% CI calculated using the variance of log(RR) based on a Poisson distribution.
§For comparisons having two reference streets, the average number of injuries of the reference streets is used.
MVO, motor vehicle occupant.
tracks was too small to determine which factors make some safer.

In one of the few comparisons of bicycling in the street versus bicycling on a separated path parallel to the street in the USA, Wachtel and Lewiston determined a relative crash risk of 1.8 for bicycling on sidewalks which had been designated as bike-ways, compared with bicycling in the adjacent street in Palo Alto, California. However, their study considered only intersection crashes, omitting non-intersection crashes that include being hit from behind, sideswiped, or struck by a car door. The authors, though, reported that 26% of cyclist–motor vehicle collisions city-wide in Palo Alto were non-intersection crashes. If authors, though, reported that 26% of cyclist

| Table 4 | Crash RR from Wachtel and Lewiston data with non-intersection crashes included* |
|---|---|---|---|---|---|---|---|---|---|
| | Sidewalk Riders | Sidewalk Crashes | Roadway Riders | Roadway Crashes | All Riders | All Crashes | RR, sidewalk versus in-street (95% CI) | p Value | y p Value |
| Intersection only§ | | | | | | | | | |
| All cyclists | 971 | 41 | 2005 | 48 | 2976 | 89 | 1.76 (1.16 to 2.68) | 0.01 | |
| Bicycling in same direction as closest traffic lane | 656 | 13 | 1897 | 43 | 2553 | 56 | 0.87 (0.47 to 1.63) | 0.56 | |
| All crashes§ | | | | | | | | | |
| All cyclists | 971 | 41 | 2005 | 79 | 2976 | 120 | 1.07 (0.73 to 1.56) | 0.79 | |
| Bicycling in same direction as closest traffic lane | 656 | 13 | 1897 | 71 | 2553 | 84 | 0.53 (0.29 to 0.96) | 0.02 | |

*Statistically significant comparisons are shown in bold.
†95% CI calculated using the variance of log(IRR) based on a Poisson distribution.
§Significance, calculated using the variance of log(IRR) based on a Poisson distribution (for comparison with original article).

What is already known on this subject

- Individuals, in particular women, children, and seniors, prefer to bicycle separated from motor traffic.
- Cycle tracks (physically-separated bicycle-exclusive paths along roads) exist and continue to be built in The Netherlands where 27% of all trips are by bicycle and 55% of bicycle riders are female.
- Engineering guidance in the United States has discouraged bicycle facilities that resemble cycle tracks, including parallel sidepaths and sidewalk bikeways, suggesting that these facilities and cycle tracks are more dangerous than bicycling in the street.

What this study adds

- Overall, 2 ½ times as many cyclists rode on the cycle tracks compared with the reference streets.
- There were 8.5 injuries and 10.5 crashes per million-bicycle kilometers respectively on cycle tracks compared to published injury rates ranging from 3.75 to 67 for bicycling on streets. The relative risk of injury on the cycle track was 0.72 (95% CI=0.60-0.85) compared with bicycling in the reference streets.
- Cycle tracks lessen, or at least do not increase, crash and injury rates compared to bicycling in the street.

IMPLICATIONS FOR POLICY

Public health and bicycling advocates in the USA have faced a dichotomy, believing from surveys and European experience that cycle tracks encourage more bicycling, yet being warned that they lead to higher crash and injury rates. Our results suggest that cycle tracks lessen, or at least do not increase, crash and injury rates compared with the street. The construction of cycle tracks should not be discouraged.

Acknowledgements The authors would like to thank Kevin Manaugh (McGill University) and Nathalie Vaisos (Montreal police), who performed the geographical queries to extract data from the crash database, and Qi Sun and Elaine Hoffman for a review of the statistics.

Funding ACL was supported by a Ruth L. Kirschstein National Research Service Award, F32 HL093859 from the National Institutes for Health, National Heart, Lung and Blood Institute. LFMM-M is supported for data collection by the Natural Sciences and Engineering Research Council of Canada (discovery grant — individual).

Competing interests None.

Ethics approval The Harvard School of Public Health IRB reviewed this protocol and found that approval was not required. The HSPH IRB made an exemption determination.

Contributors PFG had full access to the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis. Conception and design: ACL and PFG. Acquisition of data: ACL, PFG, PM and LFMM. Analysis and interpretation of data: ANL, PFG, PM, LFMM-M, WCW and JTD. Drafting of manuscript: ACL, PFG. Critical revision for intellectual content: ACL, PFG, PM, LFMM-M, WCW and JTD. Statistical expertise: ACL, PFG, PM, LFMM-M, WCW and JTD. Administrative, technical or material support: WCW. Study supervision: PFG, WCW and JTD.
REFERENCES


