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Effectiveness of a bicycle skills training intervention on increasing bicycling and confidence: A longitudinal quasi-experimental study

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A B S T R A C T

Background: Bicycling shows potential for addressing both health and transportation challenges. One strategy to encourage more people to bicycle is skills training courses; however, there is limited evidence for their effectiveness, especially longer-term. We assessed the impact of adult bicycle skills training programs offered in Metro Vancouver, Canada, using a longitudinal, quasi-experimental study design to compare changes in bicycling and confidence over time between course participants and a comparison group.
Methods: Bicycle courses delivered by accredited instructors, 2 to 4.5 hours in duration, aimed to increase participant comfort level to ride on residential and urban streets through teaching in-person and on-road traffic handling skills. We collected data in 2016 and 2017 through online questionnaires at baseline, 1, 3, and 12 months post-course, and used mixed models to assess changes.
Results: We enrolled 135 course and 43 comparison participants. At baseline, 32 participants reported no bicycling; 18 started bicycling during the study. Adjusted models did not find different trajectories for course and comparison participants for bicycling overall (RR = 0.99, 95% CI: 0.96, 1.02) or for any specific purpose (commuting RR = 1.03, 95% CI: 0.99, 1.08; errands RR = 0.97, 95% CI: 0.93, 1.01; leisure RR = 0.96, 95% CI: 0.93, 1.00), or for confidence. Conclusion: Bicycle courses aim to address individual-level barriers to bicycling, such as skills, knowledge, and confidence, but such courses may not be enough to overcome other barriers. Bicycle courses should be combined with environmental and other means of support to achieve greater impact on bicycling.

1. Background

Active transport (walking, bicycling, and relatedly public transport) has multiple benefits, including environmental, congestion, and health benefits (Götschi et al., 2016; Zahabi et al., 2016). For these reasons, increasing the number of people using bicycles for transportation has become a public health and sustainability goal. Bicycling behaviours depend on multiple intersecting variables, such as socio-demographic, attitudinal, and environmental characteristics that vary by trip purpose and throughout the life course (Buehler and Pucher, 2012; Chatterjee et al., 2013; Heinen et al., 2010; Willis et al., 2015). Notably, studies have found that safety concerns about sharing the road with motorized vehicles pose a major barrier in people's decisions about whether to bicycle (Fishman et al., 2012), as do related aspects such as confidence (Willis et al., 2015; Xing et al., 2010).

Many bicycle skills training courses ("courses") aim to enhance confidence and bicycling skills through education and opportunities to practice (Hawley and Mackie, 2015; Johnson and Margolis, 2013; Rissel and Watkins, 2014; Rowe et al., 2016; Telfer et al., 2006; Zander et al., 2013). Countries with low bicycling prevalence (such as Canada and the US) often lack universal school-based bicycling education, meaning the majority of the population has never received formal instruction for bicycling. Courses can address individual-level barriers such as low confidence, not knowing rules, or insufficient bicycle handling skills (Handy et al., 2014), although cannot directly modify systemic barriers such as distance, infrastructure, or weather. Bicycle courses designed for adults differ from children's courses in several

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Table 1
Summary of adult bicycle skills training studies.

Author, Year, Country	Publication type	Study design(s); sampling strategy [a], sample size	Follow up after training	Bicycling frequency measures	Direction of change in bicycle frequency relative to baseline	Course description[b] (name; road ride component; group or 1:1 format; duration)
Bernstein et al. (2017), US	Peer-reviewed publication	Pre-post questionnaire; randomized control trial; pre n = 38, 3 month n = 26, 5 month n = 26	Immediately after program delivery (3 months from baseline); 5 months from baseline	# days/previous week bicycling for 1) commuting, 2) errands, 3) leisure	1) no change 2) increase 3) increase	Road ride; 10 group sessions over 12 weeks
Hawley and Mackie (2015), NZ	Evaluation report	Post-intervention retrospective questionnaire; n = 86	unclear	# days/month bicycled before course compared to # days/ previous month bicycled	Increase	Beginner: no road ride Cycling on the road: road ride
Johnson and Margolis (2013), UK	Peer-reviewed publication	Pre-post questionnaire; pre n = 471, 3 month n = 130	3 months	1) # days/previous week bicycling >30 min; 2) # days/previous week bicycled to work	1) increase 2) increase	Bikeability[c]; road ride for levels 2 & 3; 1:1 sessions; up to 4 h (4 × 1 h sessions)
Rissel and Watkins (2014), AU	Peer-reviewed publication	Pre-post questionnaire; random sampling; pre n = 4145, 3 month n = 423, 12 month n = 125	3 months; 12 months	1) bicycle in previous week (y/n) 2) bicycle in previous month (y/n)	1) increase 2) increase	Austcycle[d]; road ride for levels 2 & 3
Rowe et al. (2016), AU	Peer-reviewed publication	Two retrospective interviews (the first shortly after intervention and second a few months later); n = 33	3–5 months	Not reported	Not reported	Austcycle[d]; road ride for levels 2 & 3
Telfer et al. (2006), AU	Peer-reviewed publication	Pre-post questionnaire and interview; pre n = 113, 2 month n = 105	2 months	1) # days/previous week bicycling; 2) mins/previous week bicycling; 3) # days/previous week bicycling to work	1) no change 2) increase 3) no change	Based on Austcycle[d]; road ride for level 2; group sessions; 6 h (2 × 3 h sessions)
Transport for London (2016), UK	Evaluation report	Pre-post questionnaire; pre n = 800, 3 month n = 258, 12 month n = 101	3 months; 12 months	# days bicycling for 1) commuting, 2) errands, 3) leisure	1) increase 2) increase 3) increase	Bikeability[c]; road ride for levels 2 & 3; group or 1:1 format
Transport for London (2017), UK	Evaluation report	Pre-post questionnaire; pre n = 724, 3 month n = 220, 12 month n = 32	3 months; 12 months	# days bicycling for 1) commuting, 2) errands, 3) leisure	1) increase 2) increase 3) increase	Bikeability[c]; road ride for levels 2 & 3; group or 1:1 format
van der Kloof et al. (2014), NL	Peer-reviewed publication	Pre-post questionnaire, n = 83 Retrospective interview, n = 19	Immediately after program delivery Unclear; up to 4 years	Not reported Not reported	Not reported Not reported	10-15 group sessions lasting 1 h to ½ day
Zander et al. (2013), AU	Peer-reviewed publication	Pre-post interviews; pre n = 17, immediately after program delivery n = 11	Immediately after program delivery	Meet 2 h/week bicycling target (y/n)	Increase	Road ride; group session; 4.5 h

[a] Sampling strategy included if described in study.
[b] Course name, road ride component, group or 1:1 delivery format, or course duration only included if described in study. All courses included time on the bicycle. Some courses follow nationally prescribed curriculum (Austcycle, Bikeability).
[c] Bikeability offers tiered training courses to address progressive ability level.
[d] Austcycle offers tiered training courses to address progressive ability level.

aspects: typically children's courses are delivered in school settings over multiple sessions, whereas adults voluntarily choose to enroll in a course. Training programs for children may be even more variable in format than those for adults. For example, children's training programs in Canadian cities may be school-based (ranging from 1-13 weeks), or outside of schools in single day workshops to multi-day camps. The heterogeneity of programing challenges comparisons. However, for courses teaching urban shared-road safety skills, course content for older children and adults may be similar (Sersli et al., 2019).

There are few studies on the effectiveness of bicycle courses for adults (Johnson and Margolis, 2013; Pucher et al., 2010). Table 1 summarizes published literature on adult bicycle courses from a recent scoping review on pre-post studies (Sersli et al., 2019), supplemented with evidence derived from different study designs. These ten studies varied in focus, design, and quality. Women (Hawley and Mackie, 2015; Johnson and Margolis, 2013; Rissel and Watkins, 2014; Telfer et al., 2006; Transport for London, 2017, 2016; van der Kloof et al., 2014) and people new to bicycling (Hawley and Mackie, 2015; Johnson and Margolis, 2013; Transport for London, 2017; van der Kloof et al., 2014) were well represented in courses. Outcomes varied: some studies measured only overall bicycling (Hawley and Mackie, 2015; Rissel and Watkins, 2014; Zander et al., 2013) while others measured bicycling for a specific trip purpose (Bernstein et al., 2017; Transport for London, 2017, 2016). Follow up periods ranged from immediately post-course to one or more years, and some studies had large losses to follow up. Only one study (a trial where 21 participants were given bicycles and participated in a course) had a comparison group (Bernstein et al., 2017). Three studies were from the same city (London) (Johnson and Margolis, 2013; Transport for London, 2017, 2016).While the small number and heterogeneity of studies makes it difficult to draw conclusive statements, the sparse evidence available suggests that training may encourage bicycling. Results also show that confidence increases after course participation (Johnson and Margolis, 2013; Rissel and Watkins, 2014; Telfer et al., 2006; Transport for London, 2017, 2016), as does recreational (leisure) bicycling. Increases in transportation bicycling uptake have been more modest.

Given the need for guidance on effective interventions to encourage bicycling, we partnered with a bicycle advocacy organization delivering bicycling courses to adults in Metro Vancouver to assess the impact that courses have on bicycling uptake. Our aim was to compare changes over one year in bicycling overall, in transportation-specific (commuting, errands) and leisure bicycling, and in confidence, between course participants and a comparison group.

2. Methods

2.1. Setting

Metro Vancouver is comprised of 22 municipalities with diverse urban form and transportation infrastructure. Its mild climate is conducive to year-round bicycling. The bicycle route network is relatively dense within the city of Vancouver, more so than in the surrounding municipalities. The city of Vancouver's network consists mainly of local street bikeways (shared roadways along local streets, typically traffic-calmed) (Winters and Zanotto, 2019). Bicycle journey-to-work mode share in Metro Vancouver is 2.3%, but 6.1% within the city of Vancouver itself, higher than other large Canadian cities such as Toronto (2.7%) or Montreal (3.9%) (Statistics Canada, 2017a, 2017b; 2017c).

2.2. Intervention: adult bicycle skills training courses

In 2016 and 2017, 28 bicycle courses were offered through a bicycling advocacy organization during the summer months (late April-early October), in the city of Vancouver (n = 23 courses) or neighbouring municipalities (n = 5). Courses were either 2 or 4.5 h in duration, consisted of one session, and delivered by accredited instructors with an instructor-student ratio of 1:6. Courses were promoted in a variety of ways: posters at libraries, community centres, bike shops, cafes; during events such as Bike to Work Week and at Car Free Days; social media posts including paid Facebook ads; and the advocacy organization's own communications channels and website. Participants registered for courses online and paid a nominal course fee ($10 to $45).

Designed by a bicycling advocacy organization, the bicycle courses addressed bicycling in urban environments on various route types, including on streets shared with cars. Participants were expected to have at least some level of bicycle proficiency (courses were advertised "for anyone who can already ride a bike"). Courses contained: 1) a theoretical component involving slides, and a learning environment encouraging classroom questions; 2) the distribution of written resources (such as municipal bicycling maps); and 3) a bicycle riding session involving practice of bicycling technique in traffic-free areas and on streets with quiet to moderate traffic.

The current 4.5 h course was designed by the advocacy organization in 2012, based on other bicycling education curricula, and in consultation with local bicycle instruction experts. The shortened 2 h launched in 2016 in response to participant requests for a condensed course. The shorter course has less time for classroom discussion, and a shortened bicycle riding session. The theoretical content and written resources are identical. The courses undergo annual updates to remain current and effective in the Metro Vancouver context. Both courses aim to increase participants' knowledge of safe cycling practices, and to build confidence riding in all traffic situations in urban environments.

To describe course content we used a taxonomy of Behaviour Change Techniques (BCTs) developed by Michie and colleagues (Michie et al., 2013). BCTs can identify the "active ingredients" of interventions and were developed to improve the clarity of intervention descriptions. Table 2 outlines the BCTs used in courses, including instruction, information, opportunities to practice skills, and opportunities to practice skills in progressively more complex street environments.

In absence of an explicit program theory of how the course leads to changes in confidence and bicycling, we mapped the BCTs used in the courses back to the Theoretical Domains Framework and corresponding Capability, Opportunity and Motivation-Behaviour (COM-B) system of behaviour change (Cane et al., 2015). Both the Theoretical Domains Framework and COM-B were developed as resources to guide intervention development. Whereas the Theoretical Domains Framework consists of dozens of

Table 2
Behaviour change techniques (BCTs) used in bicycle skills training intervention.

BCT #	BCT description	Course content example	Theoretical Domains Framework	Capability, Opportunity and Motivation-Behaviour (COM-B)
4.1	Instruction on how to perform the behaviour	Visual and verbal instruction about observing traffic rules as a bicyclist (e.g., road position, stop signs, left-turns), route-planning (using paper and online bicycle maps), using public transit with bicycle	Knowledge Skills Belief about capability	Capability Capability Motivation
5.1	Information about health consequences	Visual and verbal information about traffic rules as applying to bicyclists, such as bicycling distance from parked cars, vehicular left-turns	Knowledge Belief about consequences	Capability Motivation
6.1	Demonstration of the behaviour	Instructors demonstrate emergency braking, shoulder-checking, hand-signals, vehicular left-turns	Skills Belief about capability	Capability Motivation
8.1	Behavioural practice/rehearsal	In a traffic-free area, participants practice bicycle skills demonstrated by instructors. On streets with quiet/moderate traffic (i.e., on local street bikeways), participants practice bicycle skills such as lane position and/or distance from parked cars, 4-way stops, vehicular left turns.	Skills Belief about capability	Capability Motivation
8.7	Graded tasks	Participants practice bicycle skills in traffic-free areas, then quiet streets (i.e., local street bikeways), then to progressively more complex street environments with moderate traffic, cumulating with a short ride on an arterial road.	Skills Belief about capability	Capability Motivation

theoretical constructs from multiple behaviour change theories sorted into 14 domains, the COM-B system is even more streamlined, hypothesizing behaviour change in terms of psychological and physical capability, physical and social opportunity, and reflective and unconscious motivational barriers and enablers (Atkins et al., 2017; Cane et al., 2012).

2.3. Study design

We used a longitudinal, quasi-experimental study design. We recruited registered participants in advance through email, and in person on the day of their course. We used two recruitment methods as many participants reported having not received an advance email invitation to the study. A research assistant recruited 50 participants in person at courses. Participants were eligible if they were aged 19 or older and had sufficient English (self-assessed) to complete the surveys (English-language only). They were sent a web link to complete baseline surveys before or within 6 h of completing their course. Participants who cancelled or missed their course were recruited for the comparison group. Comparison participants were screened to ensure they had not attended other courses that summer. All participants were offered $10 gift card compensation for completed questionnaires.

Questionnaires included bicycling behaviours and attitudes, neighborhood perceptions, individual and household demographics, and residential postal code. Data were collected across four time points: baseline, 1, 3, and 12 months follow up. Our interest to assess longer term changes in bicycling combined with seasonal variations in a rainy climate suggested 12 months to be an appropriate follow up. The Simon Fraser University Research Ethics Board (2015s0220) granted ethics approval for this study.

2.4. Measures

2.4.1. Outcome: bicycling

We assessed bicycling for three purposes: for commuting (i.e., “to work or school”), for errands (i.e., “for errands or shopping”), and for leisure (i.e., “outdoors for fun or exercise”). For each purpose, participants reported how many days in the past month they bicycled, from a set of discrete categories (e.g., 1–3 days in the past month). The midpoint of each range was used to calculate the number of days per month. We calculated days of overall bicycling by summing the days of commuting, errands, and leisure for each participant.

2.4.2. Outcome: confidence

We used three items for confidence that relate to aspects targeted during the course. Participants were asked to rate their degree of confidence based on the following: (1) knowing how to ride a bicycle; (2) bicycling on a street with cars; (3) bicycling on a path away from traffic; (4) using a map to select a route; (5) bicycling for daily travel; (6) knowing where safe routes are located; (7) bicycling with things to carry; (8) bicycling in rainy weather; and (9) bicycling with children. For analysis, we categorized the five-point Likert responses as confident (“strongly agree”, “agree”) or not confident (“neither agree nor disagree”, “disagree,” and “strongly disagree”).

2.4.3. Primary variables

To assess the effect of the course over time, we treated time as a continuous variable (0, 1, 3, 12 months). We used a treatment variable to indicate if participants were in the intervention (attended the course) or comparison group (signed up but did not attend the course). The interaction term (time*treatment) was our primary coefficient of interest, as it indicates the differential change across time in bicycling for intervention and comparison participants.

2.4.4. Covariates

Demographic information was collected at baseline. Participants were asked to report their gender, age, education, ethnicity, number of years lived in Canada, income, and number of children under 17 years in the household. Additional information was collected at each measurement period, including access to a bicycle, access to a motor vehicle, employment and student status, and residential postal code. In models we included the following covariates: age (<40 years versus ≥ 40 years); city (Vancouver, other); Bike Score® (a composite measure based on density of bike lanes, hilliness, destinations, and road connectivity) (Winters et al., 2016)) at home residence. We also included seasonality, as participants enrolled in courses throughout the summer months, meaning that those who enrolled in a bicycle course in August or later had their 1 and/or 3 month follow up measures during or after October, when the weather in Metro Vancouver becomes cooler and rainier. To control for seasonality, we used the season of the course (“April–July” or “August–October”).

2.5. Statistical analyses

We used descriptive statistics to present demographic characteristics of the treatment groups at baseline, and we assessed differences in factors related to bicycling between treatment groups using t-tests for continuous variables and chi-square analyses for categorical variables. To control for initial group differences, we included characteristics that were significant at $p < 0.05$ as covariates in our adjusted model, plus gender.

To account for dependence of multiple measures and variability between individuals we used mixed effects modelling where the four observations (0, 1, 3, 12 months) were nested within participants, and participant treated as a random effect. We used negative binomial mixed models to assess changes in bicycling (days per month) and logistic mixed models to assess changes in confidence over time.

To select parsimonious models, we used a multi-phase process. We started with an unconditional model without explanatory variables. We next introduced the primary variables (time, treatment) for a two-way interaction of time by treatment group, and then added covariates to adjust the model. We determined the optimal random effects structure by using maximum likelihood estimation

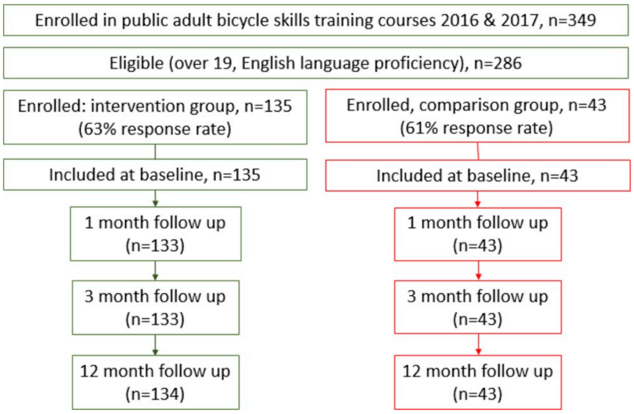

Fig. 1. Summary of recruitment and study participation.

Table 3
Characteristics of intervention and comparison participants at baseline.

Characteristics at baseline		Intervention (n = 135) n (%)	Comparison (n = 43) n (%)	P-value[a,b]
Demographic				
Gender (women)		93 (68.9%)	33 (76.7%)	0.30[a]
Age (under 40 years old)		59 (43.7%)	27 (62.8%)	0.04[a]
Education, graduated university		104 (77.0%)	31 (72.1%)	0.60[a]
Household income	Under $50,000	30 (22.2%)	12 (27.9%)	0.80[a]
	$50,000-$100,000	52 (38.5%)	15 (34.9%)	
	Over $100,000	22 (16.3%)	8 (18.6%)	
Settlement status	In Canada < 5 years	17 (12.6%)	7 (16.3%)	0.50[a]
	In Canada > 5 years	50 (37.0%)	12 (27.9%)	
	Born in Canada	68 (50.4%)	24 (55.8%)	
Ethnicity/race (self-identify as White)		67 (49.6%)	20 (46.5%)	0.90[a]
Employment, at least part-time		105 (77.8%)	37 (86.0%)	0.30[a]
Children < 17 at home (yes)		51 (37.8%)	12 (27.9%)	0.30[a]
Access to bike (yes)		124 (91.9%)	37 (86.0%)	0.40[a]
Access to car (yes)		106 (78.5%)	34 (79.1%)	1.00[a]
Bike Score® at home residence (mean, SD)		83.5 (19.6)	75.7 (24.8)	0.10[b]
Residing in Vancouver (yes)		90 (66.7%)	21 (48.8%)	0.05[a]
Season of study enrollment (April–July)		93 (68.9%)	11 (25.6%)	< 0.01[a]
Bicycle frequency[c]				
Bicycled zero days past month, any purpose		20 (14.8%)	12 (27.9%)	0.09[a]
Bicycled > 5 days past month, any purpose		74 (54.8%)	18 (41.9%)	0.02
Bicycled zero days past month, commuting		66 (57.4%)	24 (57.1%)	1.00[a]
Bicycled > once/week past month, commuting		35 (30.4%)	12 (28.6%)	1.00[a]
Bicycled zero days past month, errands		68 (50.4%)	28 (65.1%)	0.10[a]
Bicycled > once/week past month, errands		17 (12.6%)	5 (11.6%)	1.00[a]
Bicycled zero days past month, leisure		37 (27.4%)	20 (46.5%)	0.03[a]
Bicycled > once/week past month, leisure		21 (15.6%)	3 (7.0%)	0.20
Confidence				
I know how to ride a bicycle, i.e., balance, steer, stop		129 (95.6%)	43 (100%)	0.40[a]
I can ride a bicycle safely on a street with cars		70 (51.9%)	19 (44.2%)	0.50[a]
I can ride a bicycle safely on a path away from traffic		123 (91.1%)	40 (93.0%)	0.90[a]
I can use a map to choose a suitable route for me to bicycle		99 (73.3%)	32 (74.4%)	1.00[a]
To ride a bicycle for daily travel would be easy		59 (43.7%)	18 (41.9%)	1.00[a]
I know where safe bike routes are		76 (56.3%)	23 (53.5%)	0.90[a]
I can travel by bicycle when I have things to carry		54 (40.0%)	16 (37.2%)	0.90[a]
I can travel by bicycle in rainy weather		39 (28.9%)	16 (37.2%)	0.30[a]
I can travel by bicycle when I have children with me		16 (11.9%)	7 (16.3%)	0.70[a]

[a] Chi-square test.
[b] Mann Whitney test.
[c] Only participants working or attending school (n = 157) were included in bicycling for commuting; all participants were included in bicycling for any purpose, errands, and leisure.

to fit and compare unconditional, base, and adjusted models, using Akaike's information criterion (AIC) to identify the best-fitting models. We also used AIC to compare models fit with Poisson and negative binomial distributions. All statistical analyses were conducted using R studio 1.1.447 using the glmmTMB and lme4 packages (Bates et al., 2014; Magnusson et al., 2017).

Table 4
Bicycling frequency and confidence for intervention and comparison groups at baseline and follow up.

Data collection time	Intervention group mean (SD) days/month	Comparison group mean (SD) days/month	P-value[a, c]
Any purpose	Intervention (n = 135)[b]	Comparison (n = 43)[b]	
Baseline	10.5 (11.9)	9.3 (13.3)	0.20
1 month	12.4 (12.9)	6.7 (10.6)	< 0.01
3 months	10.0 (12.0)	5.1 (11.3)	< 0.01
12 months	11.3 (12.7)	8.0 (13.1)	0.08
Commuting	Intervention (n = 115)[b]	Comparison (n = 42)[b]	
Baseline	5.1 (7.7)	5.0 (7.8)	1.00
1 month	6.1 (8.1)	3.5 (6.5)	0.05
3 months	4.8 (7.2)	2.5 (5.8)	0.01
12 months	5.3 (7.4)	3.0 (5.4)	0.10
Errands	Intervention (n = 135)[b]	Comparison (n = 43)[b]	
Baseline	2.8 (5.2)	2.0 (3.9)	0.20
1 month	3.3 (5.3)	1.3 (2.4)	< 0.01
3 months	3.1 (5.4)	1.4 (3.5)	< 0.01
12 months	3.0 (5.3)	2.0 (4.6)	0.30
Leisure	Intervention (n = 135)[b]	Comparison (n = 43)[b]	
Baseline	3.3 (3.8)	2.4 (4.4)	0.04
1 month	4.3 (4.8)	2.1 (3.6)	< 0.01
3 months	3.0 (4.4)	1.3 (3.2)	< 0.01
12 months	3.7 (4.7)	3.2 (5.1)	0.40
Can ride a bicycle safely on a street with cars	Intervention (n = 135)	Comparison (n = 43)	
	Number, % confident	Number, % confident	
Baseline	70 (51.9%)	19 (44.2%)	0.50
1 month	108 (81.8%)	25 (58.1%)	< 0.01
3 months	109 (82.0%)	25 (58.1%)	< 0.01
12 months	107 (79.9%)	27 (62.8%)	0.04
Can use a map to choose a suitable route for me to bicycle			
Baseline	99 (73.3%)	32 (74.4%)	1.00
1 month	116 (88.5%)	28 (65.1%)	< 0.01
3 months	122 (91.7%)	29 (67.4%)	< 0.01
12 months	122 (91.7%)	32 (74.4%)	0.01
Know where safe bike routes are			
Baseline	76 (56.3%)	23 (53.5%)	0.90
1 month	108 (81.8%)	24 (55.8%)	< 0.01
3 months	113 (85.0%)	22 (51.2%)	< 0.01
12 months	105 (78.4%)	27 (62.8%)	0.07

[a] Chi-square test.
[c] Mann Whitney test.
[b] Only participants working or attending school were included in bicycling for commuting; all participants were included in bicycling for errands and leisure.

3. Results

3.1. Sample characteristics

During the 2016 and 2017 season, 349 people registered in 28 adult bicycle training courses (Fig. 1). A total of 63 were ineligible (56 under 19 years of age, 7 with low English). Of 286 eligible students, 178 enrolled in our study (response rate 62%). Table 3 shows participant demographics at baseline. The majority of participants were women, university-educated, had access to cars, and were living in households without children. Of the 178 participants, 135 (76%) were in the intervention group and 43 (24%) in the comparison group. Of the 135 intervention participants, 27 (20%) took the shorter 2 h course. Loss to follow up over 12 months was low (< 1%) with no loss in the comparison group. Baseline differences between the intervention and comparison groups were age, city of residence, and season of study enrollment.

3.2. Changes in bicycling participation, frequency, and confidence

We examined the proportion of participants not bicycling at baseline (Table 3). At baseline, 18% (32/178) of participants reported zero days of bicycling in the past month. Of these, 18 (13 intervention, 5 comparison) started bicycling during the study, whereas 14 (7 intervention, 7 comparison) did not bicycle at all during the entire study duration. When we examined bicycling by trip purpose at baseline, 57% (90/157) of participants reported zero days of bicycling for commuting; 53.9% (96/178) for errands; 32% (57/178) for leisure. When participants did use bicycles for commuting, they did so often: the majority (70% or 47/67) commute bicycled more than once per week at baseline.

We examined the proportion of participants that said they felt confident for each of the nine confidence measures (Table 3). At baseline, there were no significant differences between treatment groups. Most participants reported feeling confident knowing how

Table 5
Negative binomial random intercept models on impact of a bicycle skills training course over one year for bicycling frequency (days per month).

	Overall		*Commuting*		*Errands*		*Leisure*	
	Base	Adjusted	Base	Adjusted	Base	Adjusted	Base	Adjusted
Fixed Effects	Rate ratio (95% CI)	Rate ratio (95% CI)	Rate ratio (95% CI)	Rate ratio (95% CI)	Rate ratio (95% CI)	Rate ratio (95% CI)	Rate ratio (95% CI)	Rate ratio (95% CI)
Time[a]	1.01 (0.98–1.04)	1.01 (0.99–1.04)	0.97 (0.93–1.01)	0.98 (0.94–1.02)	1.02 (0.99–1.06)	1.03 (0.99–1.07)	1.04 (1.00–1.07)	1.04 (1.00–1.07)
Treatment: course[b]	**2.19 (1.42–3.39)**	1.41 (0.89–2.23)	2.00 (0.89–4.48)	1.04 (0.44–2.45)	**2.69 (1.37–5.30)**	1.66 (0.80–3.43)	**2.24 (1.48–3.38)**	**1.75 (1.13–2.73)**
Time*treatment[c]	0.99 (0.96–1.01)	0.99 (0.96–1.02)	1.03 (0.98–1.07)	1.03 (0.99–1.08)	0.97 (0.93–1.01)	0.97 (0.93–1.01)	0.96 (0.93–1.00)	0.96 (0.93–1.00)
Covariates								
Gender: men[d]		**1.82 (1.26–2.62)**		**2.93 (1.43–5.99)**		1.62 (0.91–2.91)		**1.64 (1.17–2.29)**
City: outside Vancouver[e]		**0.52 (0.38–0.71)**		**0.31 (0.17–0.54)**		**0.30 (0.18–0.50)**		0.82 (0.61–1.12)
Season: Aug-Oct[f]		**0.60 (0.41–0.86)**		0.55 (0.27–1.12)		0.67 (0.37–1.21)		0.71 (0.51–1.00)
Age: over 40[g]		1.07 (0.76–1.51)		0.92 (0.47–1.80)		0.95 (0.55–1.65)		1.06 (0.77–1.46)
Random Effects								
τ00 (Random intercept)	1.17_{ID}	1.00_{ID}	3.82_{ID}	3.37_{ID}	2.47_{ID}	2.27_{ID}	0.80_{ID}	0.73_{ID}
σ2 (Residual variance)	20.1	18.61	18.83	17.14	4.21	3.75	3.55	3.52
Observations	712	705	619	617	707	705	707	705

[a] Time (0–12 months).
[b] Treatment (comparison is reference).
[c] Interaction (time*comparison is reference).
[d] Gender (women is reference).
[e] City of residence (Vancouver is reference).
[f] Season (April–July is reference).
[g] Age (under 40 is reference).

Table 6
Logistic random intercept models on impact of a bicycle skills training course over one year for odds of being confident.

	I can ride a bicycle safely on a street with cars		*I can use a map to choose a suitable route for me to cycle*		*I know where safe bike routes are*	
	Base	Adjusted	Base	Adjusted	Base	Adjusted
Fixed Effects	Odds ratio (95% CI)	Odds ratio (95% CI)	Odds ratio (95% CI)	Odds ratio (95% CI)	Odds ratio (95% CI)	Odds ratio (95% CI)
Time[a]	1.12 (1.05–1.19)	**1.12 (1.06–1.19)**	**1.14 (1.05–1.24)**	**1.17 (1.07–1.27)**	**1.07 (1.02–1.14)**	**1.08 (1.02–1.15)**
Treatment: course[b]	0.27 (0.09–0.79)	0.32 (0.10–1.00)	**0.26 (0.07–0.97)**	**0.38 (0.09–1.57)**	**0.24 (0.08–0.68)**	**0.29 (0.09–0.94)**
Time*treatment[c]	0.97 (0.87–1.09)	0.96 (0.86–1.08)	0.91 (0.80–1.04)	0.89 (0.78–1.02)	0.99 (0.89–1.10)	0.99 (0.88–1.10)
Covariates						
Gender: men[d]		**7.08 (2.45–20.45)**		**4.85 (1.36–17.26)**		2.54 (0.92–6.98)
City: outside Vancouver[e]		1.41 (0.62–3.21)		1.27 (0.47–3.49)		0.74 (0.32–1.69)
Season: Aug-Oct[f]		0.80 (0.32–2.00)		0.77 (0.24–2.45)		1.07 (0.41–2.75)
Age: over 40[g]		0.75 (0.32–1.80)		2.67 (0.89–8.04)		1.73 (0.70–4.28)
Random Effects						
τ00 (Random intercept)	3.29	3.29	3.29	3.29	3.29	3.29
σ2 (Residual variance)	4.98 ID	4.73 ID	7.28 ID	6.88 ID	4.79 ID	5.04 ID
Observations	705	704	704	703	706	705

[a] Time (0–12 months).
[b] Treatment (comparison is reference).
[c] Interaction (time*comparison is reference).
[d] Gender (women is reference).
[e] City of residence (Vancouver is reference).
[f] Season (April–July is reference).
[g] Age (under 40 is reference).

to ride a bicycle (97%) and riding a bicycle safely on a path away from traffic (92%). Participants were least confident travelling by bicycle with things to carry (39%), in rainy weather (31%), or with children (15%).

Table 4 summarizes bicycle behaviours at each time point. Participants in both groups tended to bicycle most often for commuting (baseline means of 5.1 and 5.0 days/month, respectively), and least often for errands (2.8 and 2.0 days/month). There were no significant differences in frequency of commute and errand bicycling between groups at baseline. At one month follow up, intervention participants increased bicycling after their course for all trip types, whereas comparison participants experienced no increase. For the confidence outcomes intervention participants increased confidence more quickly than comparison participants.

3.3. Regression analysis for bicycling and confidence

We used negative binomial mixed models (Table 5) to assess changes in bicycling over time. Time was modelled as a continuous variable across one year; we also modelled time categorically to assess short-term changes (Table S1 in Supplementary Material). Rate ratios represent the percentage change in the number of days bicycled in the previous month, and the interaction term represents the differential change over time between the intervention and comparison groups. In the adjusted models for overall bicycling, there were no significant interaction or main effects indicating there was no change over time in the number of days per month participants rode bicycles. Likewise, in the adjusted models for commuting and errands there was no change over time in bicycling to work or for errands. We saw that men had higher rates of bicycling overall and to work compared to women, and participants living outside the city of Vancouver had much lower rates of bicycling overall, to work, or using bicycles for errands. Participants registering for courses later in the season had lower rates of overall bicycling.

For leisure bicycling, the models show that at baseline, intervention participants rode more often than comparison group members, although the difference was attenuated when adjusted for gender (RR = 1.75, 95% CI: 1.13, 2.73). Additional tests revealed that intervention participants significantly increased leisure bicycling between baseline and 1 month follow up (RR = 1.27, 95% CI: 1.05, 1.54), but the overall change between baseline and 12 month follow up was not significant. Men had higher rates of leisure bicycling compared to women.

We used logistic mixed models (Table 6) to assess changes in confidence for three aspects of confidence that were targeted during the course. For items, “I can ride a bicycle safely on a street with cars”, “I can use a map to choose a suitable route for me to bike”, and “I know where safe bike routes are”, the interaction term was not significant, meaning the probability of feeling confident for any confidence measure did not differ as a function of being in the intervention or comparison group. Additional post hoc analysis showed no difference in change in bicycling for any trip type between short and long course participants. In terms of confidence change over time, shorter course participants had higher odds of feeling confident in using a map to choose a suitable route than the longer course participants but confidence intervals are wide (OR = 3.73, 95% CI: 1.26, 11.07) indicating a larger sample is warranted.

4. Discussion

Given the multiple health benefits, increasing bicycle use is desirable from an individual and societal perspective. This study assessed the impact of a community-based bicycling training skills program related to increases in bicycling frequency and confidence over one year. We compared 135 intervention participants with a comparison population and examined the number of days participants reported using bicycles overall, as well as for commuting, errands, and leisure. We found that participants bicycled more frequently for commuting than for either errands or leisure, but the highest participation rates (i.e., if participants bicycled at all) was for leisure. One year after the course, we did not see lasting increases in bicycling in course participants as compared to the comparison group. We also examined changes in confidence pertaining to bicycling on streets with cars, using maps to find routes, or knowing about safe routes, but found no lasting effect of the program on confidence.

Our findings contrast with a handful of studies on adult bicycle courses that have documented significant increases in bicycling (Bernstein et al., 2017; Johnson and Margolis, 2013) or confidence (Bernstein et al., 2017; Rissel and Watkins, 2014; Telfer et al., 2006; Transport for London, 2016). Potential reasons may be differences in course content or duration, participant demographics, or other contextual factors. It may be that this particular course configuration, a brief 2–4.5 h mixed classroom/on-road design, was not sufficient to have lasting impacts for the average participant. Alternatively, it may be the course did not address critical barriers facing participants. For example, the Behaviour Change Techniques that were used in the bicycle course (Table 2) focused on teaching skills and knowledge (addressing capability and motivation of COM-B) but did not target social or physical opportunity. Reviews suggest effective strategies for the initiation and maintenance of physical activity include self-regulation techniques such as goal setting, self-monitoring, action planning, or prompts (Hynynen et al., 2016; Murray et al., 2017), whereas interventions aiming to change transportation behaviour may need to incorporate different techniques to actually disrupt behaviour patterns (Arnott et al., 2014). Thus, it may be that participants who took the course with the intent to bicycle more often need more opportunities to ride bicycles, in supportive or social settings, to put their new skills into practice. Research shows that ongoing support is vital for physical activity maintenance (Murray et al., 2017).

4.1. Bicycling by trip purpose

The majority of course participants were already bicycling—about half were bicycling five or more days per month. To better understand bicycling behaviours and identify opportunities for increased active transportation, we captured bicycling for different purposes. This is important for several reasons. First, the drivers for using a bicycle differ by trip purpose. Commuters and recreational bicyclists have different characteristics and preferences, and tailored interventions may be needed to facilitate mode shift (Buehler and Pucher, 2012; Heesch et al., 2014). For example, for those who feel bicycling with traffic is a barrier, bicycling for work or shopping may be harder to accomplish than bicycling for leisure. Second, many cities have goals to replace short-distance car trips with active transport modes (City of Vancouver, 2012; Mitra et al., 2016). Data that distinguishes bicycling for transportation from bicycling for leisure is vital to assess progress toward this goal. Third, commuting is often a strategic target for mode shift because it is a repetitive activity and can be potentially incorporated into daily routines (Heinen et al., 2010), although work trips constitute only ~20% of all travel (Banister et al., 1997).

4.1.1. Commuting

If participants commuted by bicycle, it was their most frequent reason for bicycling. As seen elsewhere (LeVine et al., 2014; Winters et al., 2010), this may arise as commuting involves travel to/from fixed locations at fairly consistent schedules, facilitating habitual patterns (Kurz et al., 2015; Stinson and Bhat, 2004). Men bicycled for commuting more often than women, congruent with well-documented gender differences in bicycling in the US, Canada, Australia, New Zealand, and UK (Garrard et al., 2012). Living in the city of Vancouver was also found to be a predictor of bicycle commuting. This could reflect the denser bicycle network found in Vancouver versus than the surrounding municipalities, as bicycle infrastructure is related to commuting (Pucher et al., 2012). Other determinants of bicycle commuting, such as distance, topography, and income (Heinen et al., 2010) were either not measured or were found to have little impact on bicycling usage over time.

4.1.2. Errands

Participants tended to bicycle for errands less frequently than for commuting or leisure. While many determinants of bicycling to work and for errands are similar (e.g. density of bicycle network, distance, secure storage), there are also differences. For example, errand trips may have more complicated trip chaining and logistics, thus making planning for errand trips harder (Stinson and Bhat, 2004). Errands were the only trip type without a gender disparity. While in our sample gender was not related to errand bicycling, previous studies have suggested that women are more likely to use bicycles for shopping, errands, or visiting people (LeVine et al., 2014), in line with a trend for women to make more household-related trips.

4.1.3. Leisure

At baseline, more participants participated in bicycling for leisure than for any other trip purpose, with two-thirds (68%) reporting bicycling for leisure in the past month. The popularity of bicycling for leisure has been highlighted previously (Goodman and Aldred, 2018; Heesch et al., 2014, 2012; Menai et al., 2015). Potential facilitators of leisure bicycling may be greater flexibility to choose the days, times of day (avoiding busy road times), or routes, as compared to commuting by bicycle (Heesch et al., 2012). Leisure bicycling affords greater flexibility and is "unconstrained by space or time" (Boyer, 2018, p. 409), making it perhaps more possible for more people. Further investigation, perhaps through qualitative research, may reveal how those bicycling for leisure may transition to transport or errand bicycling. We did see short-term increases in bicycling for leisure amongst course participants relative to the comparison, although this was not sustained at the one year follow up.

4.2. Intervention impact on confidence

The course was not associated with increases in confidence for bicycling on streets with cars, using maps to find bicycling routes, or knowing the location of safe bicycle routes. That said, confidence started quite high; at baseline at least 50% of participants were already confident. Men were more confident on most measures as is consistent with other studies (Heesch et al., 2012). Also, we observed that confidence increased in both course participants and the comparison group over the one year follow up. It may be that the comparison group, people who had registered for a course but not taken it, had been motivated to find other ways to support their bicycling training. Confidence to bicycle on streets with cars is important in the Vancouver context, as much of the bicycle network is composed of local street bikeways (shared-roadways). Route finding is also important, as different route types carry different bicycling safety risk (Winters et al., 2013). For this reason the course emphasized using municipal bicycle maps and Google Maps' Cycling Directions to plan routes and locate dedicated bicycle infrastructure—including local street bikeways (often not visible from public transit routes or primary arterial roads). Although we modelled only the three confidence areas targeted by the course, we asked about nine different aspects of bicycling confidence. At baseline, participants were least confident travelling by bicycle with things to carry, in rainy weather, or with children. These are topics practitioners should consider addressing to promote bicycling for utilitarian purposes.

4.3. Implications for policy and practice

Bicycle skills training courses have potential to address individual-level barriers such as low confidence, not knowing rules, or insufficient bicycle handling skills (Handy et al., 2014), although cannot directly address systemic barriers such as distance, infrastructure, or weather. On their own, courses may not be potent enough to overcome systemic barriers to bicycling. For this reason, experts suggest that bicycle courses may have greatest potential for increasing ridership when nested within comprehensive packages of integrated and complementary interventions to encourage bicycling (Johnson and Margolis, 2013; Pucher et al., 2010; Rissel and Watkins, 2014). Physical infrastructure, education programs, promotional activities and incentives need to be designed to interact with each other to leverage synergies (Pucher et al., 2010). Additionally, bicycle courses could be combined with social opportunities to engage in bicycling, such as group rides or follow up sessions involving bicycling on streets. Our findings suggest that courses facilitate short-term increases in leisure bicycling. The increase in leisure bicycling was shortly after the intervention, suggesting follow up support for trainees may be helpful to sustain their bicycling. Bicycling for errands was the least frequent trip purpose and did not increase over time. If cities hope to encourage bicycling for both commuting and errand trips, then common barriers need addressing.

This study focused on the outcomes of reported changes in bicycling frequency and confidence, but courses address other important elements that ultimately shape behaviour, such as shifting personal perceptions and meanings about bicycling (Schneider et al., 2018). Our own interviews with a subset of course participants found that they felt the course had made them more aware as drivers how to share the road with bicyclists, and that formal training had enabled them to model competent bicycling behaviour to children and peers. These shifts may be especially relevant in places such as Vancouver without universal school-based bicycling education. To enhance access, bicycle courses would ideally be free or minimal cost and offered on broader scale including in workplaces and community centres.

In this study, course participants were mainly women though the course was not specifically women-oriented. The gender disparity in adult bicycle courses has been found elsewhere (Rowe et al., 2016; Sersli et al., 2019). In interviews with women (we did not interview men) we heard that participants enrolled in courses to improve confidence to ride on streets with cars, and to be more aware of rules pertaining to bicycling on shared streets with other users. Societal perceptions and meanings about bicycling may influence course participation. For example, some participants felt that bicycle courses were commonly perceived by others as being for children or those with very low skill. To broaden the appeal of courses and their uptake, courses could be advertised as beneficial for a variety of skill and confidence levels.

5. Strengths and limitations

Major strengths of this study are its longitudinal quasi-experimental design which enabled us to assess bicycling trajectories for individuals over time, the high (99%) retention rate, and the incorporation of a comparison group. Comparison groups are often missing from bicycle intervention evaluations (Pucher et al., 2010), and to our knowledge this is only the second study of adult bicycle skills training with a comparison group. Our comparison group consisted of people who enrolled in but did not attend a course. We selected this group intentionally to use a comparison group that was interested in bicycling. In the absence of attending the course, comparison participants may have found other avenues to support bicycling behaviours, which may have attenuated differences in changes in bicycling and confidence observed in the two groups. Our comparison group was smaller than the intervention group, a function of the recruitment method. A greater sample size overall would be possible with additional years of data collection, beyond the two seasons used here. The comparison group could expand if eligibility criteria were relaxed, or if randomization to course timing were possible. There may have been social desirability bias in the reporting of bicycling behaviour in the online surveys, however, any bias would be non-differential across course and comparison groups. To note, people were enrolled continuously: people who took courses later in the summer were more subject to seasonal effects in follow up (especially at 3 months), and the comparison group had a greater proportion of late enrollers. We aimed to address this by controlling for seasonality.

Finally, it is likely there was some overlap between the different "types" of bicycling, especially when trip purposes where combined. Future work may use more nuanced survey questions, or employ qualitative methods to more specifically understand trip chaining, complex trip characteristics, and how participation in training courses may shape people's overall bicycling trajectories.

6. Conclusions

Our research adds to the few studies assessing the impact of bicycle skills training on bicycle uptake in adults. We did not find increases in overall bicycling or for commuting or errands, nor was the course associated with increases in confidence, relative to a comparison group. We found modest increases at one month follow up in leisure bicycling among those who completed a course, although increased bicycling was not sustained over one year. We encourage future studies to include multiple follow up time points to study maintenance in behaviour change, and to include bicycling for different trip purposes. Bicycle infrastructure is a necessary prerequisite to increase bicycling. Bicycle courses are a part of an overall strategy to increase bicycling, but they cannot substitute for a safe and attractive bicycling environment.

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Conflict of interest

None.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jth.2019.100577.

References

Arnott, B., Rehackova, L., Errington, L., Sniehotta, F.F., Roberts, J., Araujo-Soares, V., 2014. Efficacy of behavioural interventions for transport behaviour change: systematic review, meta-analysis and intervention coding. Int. J. Behav. Nutr. Phys. Act. 11, 133. https://doi.org/10.1186/s12966-014-0133-9.

Atkins, L., Francis, J., Islam, R., O'Connor, D., Patey, A., Ivers, N., Foy, R., Duncan, E.M., Colquhoun, H., Grimshaw, J.M., Lawton, R., Michie, S., 2017. A guide to using the Theoretical Domains Framework of behaviour change to investigate implementation problems. Implement. Sci. 12, 77. https://doi.org/10.1186/s13012-017-0605-9.

Banister, D., Watson, S., Wood, C., 1997. Sustainable Cities: transport, energy, and urban form. Environ. Plan. Plan. Des. 24, 125–143. https://doi.org/10.1068/b240125.

Bates, D., Maechler, M., Bolker, B., Walker, S., 2014. lme4: Linear Mixed-Effects Models Using Eigen and S4.

Bernstein, R., Schneider, R., Welch, W., Dressel, A., DeNomie, M., Kusch, J., Sosa, M., 2017. Biking for health: results of a pilot randomized controlled trial examining the impact of a bicycling intervention on lower-income adults. Wis. Med. J. 116, 154–160.

Boyer, R., 2018. Recreational bicycling as a "gateway" to utility bicycling: the case of Charlotte, NC. Int. J. Sustain. Transport. 12, 407–415. https://doi.org/10.1080/15568318.2017.1382622.

Buehler, R., Pucher, J., 2012. Cycling to work in 90 large American cities: new evidence on the role of bike paths and lanes. Transportation (Amst). 39, 409–432. https://doi.org/10.1007/s11116-011-9355-8.

Cane, J., O'Connor, D., Michie, S., 2012. Validation of the theoretical domains framework for use in behaviour change and implementation research. Implement. Sci. 7, 37. https://doi.org/10.1186/1748-5908-7-37.

Cane, J., Richardson, M., Johnston, M., Ladha, R., Michie, S., 2015. From lists of behaviour change techniques (BCTs) to structured hierarchies: comparison of two methods of developing a hierarchy of BCTs. Br. J. Health Psychol. 20, 130–150. https://doi.org/10.1111/bjhp.12102.

Chatterjee, K., Sherwin, H., Jain, J., 2013. Triggers for changes in cycling: the role of life events and modifications to the external environment. J. Transp. Geogr. 30, 183–193. https://doi.org/10.1016/j.jtrangeo.2013.02.007.

City of Vancouver, 2012. Greenest City Action Plan. City of Vancouver, Vancouver.

Fishman, E., Washington, S., Haworth, N., 2012. Understanding the fear of bicycle riding in Australia. J. Australas. Coll. Road Saf. 13, 19–27.

Garrard, J., Handy, S., Dill, J., 2012. Women and cycling. In: Pucher, J., Buehler, R. (Eds.), City Cycling. The MIT Press, Cambridge MA, pp. 211–234. https://doi.org/10.1080/01441647.2013.782592.

Goodman, A., Aldred, R., 2018. Inequalities in utility and leisure cycling in England, and variation by local cycling prevalence. Transport. Res. F Traffic Psychol. Behav. 56, 381–391. https://doi.org/10.1016/j.trf.2018.05.001.

Götschi, T., Garrard, J., Giles-Corti, B., 2016. Cycling as a part of daily life: a review of health perspectives. Transport Rev. 36, 45–71. https://doi.org/10.1080/01441647.2015.1057877.

Handy, S., van Wee, B., Kroesen, M., 2014. Promoting cycling for transport: research needs and challenges. Transport Rev. 34, 4–24. https://doi.org/10.1080/01441647.2013.860204.

Hawley, G., Mackie, H., 2015. Evaluation of Auckland's Adult Cycle Training Programme. Mackie Research & Consulting, Auckland.

Heesch, K.C., Sahlqvist, S., Garrard, J., 2012. Gender differences in recreational and transport cycling: a cross-sectional mixed-methods comparison of cycling patterns,

motivators, and constraints. Int. J. Behav. Nutr. Phys. Act. 9, 1–12. https://doi.org/10.1186/1479-5868-9-106.
Heesch, K.C., Giles-Corti, B., Turrell, G., 2014. Cycling for transport and recreation: associations with socio-economic position, environmental perceptions, and psychological disposition. Prev. Med. (Baltim). 63, 29–35. https://doi.org/10.1016/j.ypmed.2014.03.003.
Heinen, E., van Wee, B., Maat, K., 2010. Commuting by bicycle: an overview of the literature. Transport Rev. 30, 59–96. https://doi.org/10.1080/01441640903187001.
Hynynen, S.-T., van Stralen, M.M., Sniehotta, F.F., Araújo-Soares, V., Hardeman, W., Chinapaw, M.J.M., Vasankari, T., Hankonen, N., 2016. A systematic review of school-based interventions targeting physical activity and sedentary behaviour among older adolescents. Int. Rev. Sport Exerc. Psychol. 9, 22–44. https://doi.org/10.1080/1750984X.2015.1081706.
Johnson, R., Margolis, S., 2013. A review of the effectiveness of adult cycle training in Tower Hamlets. Transport Pol. 30, 254–261. https://doi.org/10.1016/j.tranpol.2013.09.005. London.
Kurz, T., Gardner, B., Verplanken, B., Abraham, C., 2015. Habitual behaviors or patterns of practice? Explaining and changing repetitive climate-relevant actions. Wiley Interdiscip. Rev. Clim. Change 6, 113–128. https://doi.org/10.1002/wcc.327.
LeVine, S., Miranda-Moreno, L., Lee-Gosselin, M., Waygood, O., 2014. Gender and the growth of cycling in a megacity region: emerging evidence from London. In: The 5th International Conference on Women's Issues in Transportation, pp. 497–508 Paris.
Transport for London, 2016. Adult Cycle Training Monitoring Final Report Financial Year 2014/15. (London).
Transport for London, 2017. Adult Cycle Training Monitoring Initial Report 2015/2016. (London).
Magnusson, A., Skaug, H.J., Nielsen, A., Berg, C.W., Kristensen, K., Maechler, M., van Bentham, K., Bolker, B., Brooks, M., 2017. glmmTMB: Generalized Linear Mixed Models Using Template Model Builder.
Menai, M., Charreire, H., Feuillet, T., Salze, P., Weber, C., Enaux, C., Andreeva, V.A., Hercberg, S., Nazare, J.-A., Perchoux, C., Simon, C., Oppert, J.-M., 2015. Walking and cycling for commuting, leisure and errands: relations with individual characteristics and leisure-time physical activity in a cross-sectional survey (the ACTI-Cités project). Int. J. Behav. Nutr. Phys. Act. 12, 150. https://doi.org/10.1186/s12966-015-0310-5.
Michie, S., Richardson, M., Johnston, M., Abraham, C., Francis, J., Hardeman, W., Eccles, M.P., Cane, J., Wood, C.E., 2013. The behavior change technique taxonomy (v1) of 93 hierarchically clustered techniques: building an international consensus for the reporting of behavior change interventions. Ann. Behav. Med. 46, 81–95. https://doi.org/10.1007/s12160-013-9486-6.
Mitra, R., Smith Lea, N., Cantello, I., Hanson, G., 2016. Cycling Behaviour and Potential in the Greater Toronto and Hamilton Area. School of Urban and Regional Planning, Ryerson University in collaboration with Toronto Centre for Active Transportation, Toronto. https://doi.org/10.13140/RG.2.1.2629.3203.
Murray, J.M., Brennan, S.F., French, D.P., Patterson, C.C., Kee, F., Hunter, R.F., 2017. Effectiveness of physical activity interventions in achieving behaviour change maintenance in young and middle aged adults: a systematic review and meta-analysis. Soc. Sci. Med. 192, 125–133. https://doi.org/10.1016/j.socscimed.2017.09.021.
Pucher, J., Dill, J., Handy, S., 2010. Infrastructure, programs, and policies to increase bicycling: an international review. Prev. Med. (Baltim). 50. https://doi.org/10.1016/j.ypmed.2009.07.028.
Pucher, J., de Lanversin, E., Suzuki, T., Whitelegg, J., 2012. Cycling in megacities: London, Paris, New York and Tokyo. In: Pucher, J., Buehler, R. (Eds.), City Cycling. The MIT Press, Cambridge MA, pp. 319–345.
Rissel, C., Watkins, G., 2014. Impact on cycling behavior and weight loss of a national cycling skills program (AustCycle) in Australia 2010–2013. J. Transp. Health 1, 134–140. https://doi.org/10.1016/j.jth.2014.01.002.
Rowe, K., Shilbury, D., Ferkins, L., Hinckson, E., 2016. Challenges for sport development: women's entry level cycling participation. Sport Manag. Rev. 19, 417–430. https://doi.org/10.1016/j.smr.2015.11.001.
Schneider, R.J., Kusch, J., Dressel, A., Bernstein, R., 2018. Can a twelve-week intervention reduce barriers to bicycling among overweight adults in low-income Latino and Black communities? Transport. Res. F Traffic Psychol. Behav. 56, 99–112. https://doi.org/10.1016/j.trf.2018.03.023.
Sersli, S., DeVries, D., Gislason, M., Scott, N., Winters, M., 2019. Changes in bicycling frequency in children and adults after bicycle skills training: a scoping review. Transp. Res. Part A Policy Pract. 123, 170–187. https://doi.org/10.1016/j.tra.2018.07.012.
Statistics Canada, 2017a. Vancouver, CY [Census Subdivision], British Columbia and Greater Vancouver, RD [Census Division], British Columbia (Table). Census Profile. 2016 Census. Statistics Canada Catalogue No. 98-316-X2016001. [WWW Document]. URL. http://www12.statcan.gc.ca/census-recensement/2016/dp-pd/prof/index.cfm?Lang=E accessed 3.27.17.
Statistics Canada, 2017b. Montréal, V [Census Subdivision], Quebec and Montréal, TÉ [Census Division], Quebec (Table). Census Profile. 2016 Census. Statistics Canada Catalogue No. 98-316-X2016001. [WWW Document]. URL. https://www12.statcan.gc.ca/census-recensement/2016/dp-pd/prof/index.cfm?Lang=E accessed 4.15.19.
Statistics Canada, 2017c. Toronto, C [Census Subdivision], Ontario and Canada [Country] (Table). Census Profile. 2016 Census. Statistics Canada Catalogue No. 98-316-X2016001. [WWW Document]. URL. https://www12.statcan.gc.ca/census-recensement/2016/dp-pd/prof/index.cfm?Lang=E accessed 4.15.19.
Stinson, M., Bhat, C., 2004. Frequency of bicycle commuting: internet-based survey analysis. Transp. Res. Rec. J. Transp. Res. Board 1878, 122–130. https://doi.org/10.3141/1878-15.
Telfer, B., Rissel, C., Bindon, J., Bosch, T., 2006. Encouraging cycling through a pilot cycling proficiency training program among adults in central Sydney. J. Sci. Med. Sport 9, 151–156. https://doi.org/10.1016/j.jsams.2005.06.001.
van der Kloof, A., Bastiaanssen, J., Martens, K., 2014. Bicycle lessons, activity participation and empowerment. Case Stud. Transport Pol. 2, 89–95. https://doi.org/10.1016/j.cstp.2014.06.006.
Willis, D.P., Manaugh, K., El-Geneidy, A., 2015. Cycling under influence: summarizing the influence of perceptions, attitudes, habits and social environments on cycling for transportation. Int. J. Sustain. Transport. 9, 565–579. https://doi.org/10.1080/15568318.2013.827285.
Winters, M., Zanotto, M., 2019. The Canadian Bikeway Comfort and Safety (Can-BICS) Classification System: A Proposal for Developing Common Naming Conventions for Cycling Infrastructure. (Vancouver).
Winters, M., Brauer, M., Setton, E.M., Teschke, K., 2010. Built environment influences on healthy transportation choices: bicycling versus driving. J. Urban Health 87, 969–993. https://doi.org/10.1007/s11524-010-9509-6.
Winters, M., Weddell, A., Teschke, K., 2013. Is evidence in practice? Review of driver and cyclist education materials with respect to cycling safety evidence. Transport. Res. Rec. J. Transp. Res. Board 35–45. https://doi.org/10.3141/2387-05.
Winters, M., Teschke, K., Brauer, M., Fuller, D., 2016. Bike Score®: associations between urban bikeability and cycling behavior in 24 cities. Int. J. Behav. Nutr. Phys. Act. 13, 1–10. https://doi.org/10.1186/s12966-016-0339-0.
Xing, Y., Handy, S., Mokhtarian, P.L., 2010. Factors associated with proportions and miles of bicycling for transportation and recreation in six small US cities. Transport. Res. Transport Environ. 15, 73–81. https://doi.org/10.1016/j.trd.2009.09.004.
Zahabi, S.A.H., Chang, A., Miranda-Moreno, L.F., Patterson, Z., 2016. Exploring the link between the neighborhood typologies, bicycle infrastructure and commuting cycling over time and the potential impact on commuter GHG emissions. Transport. Res. Transport Environ. 47, 89–103. https://doi.org/10.1016/j.trd.2016.05.008.
Zander, A., Passmore, E., Mason, C., Rissel, C., 2013. Joy, exercise, enjoyment, getting out: a qualitative study of older people's experience of cycling in Sydney, Australia. J. Environ. Public Health 2013, 547453. https://doi.org/10.1155/2013/547453.