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

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Abstract

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.

Keywords: bicycle; training; course; participation; evaluation; behaviour change

1.0 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 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.

There are few studies on the effectiveness of bicycle courses for adults (Johnson and Margolis, 2013; Pucher et al., 2010) (Table 1). Table 1 summarizes published literature on adult bicycle courses from a recent scoping review on pre-post studies (Sersli et al., 2018), 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.

[TABLE 1 here]

2.0 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 than its surrounding municipalities. Bicycle journey-to-work mode share in Metro Vancouver is 2.3%, but 6.1% within the city of Vancouver itself (Statistics Canada, 2017).

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 each between 2 and 4.5 hours in duration, consisting of one session, and delivered by accredited instructors with an instructor-student ratio of 1:6. Participants registered for courses online and paid a nominal course fee ($10 to $45).

The bicycle courses were designed to address bicycling in urban environments, 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.

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 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).

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 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, 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, then to progressively more complex street environments with moderate traffic.	Skills Belief about capability	Capability Motivation

2.3 Study design

We used a longitudinal, quasi-experimental study design. We recruited registered participants through email and in person. Participants were eligible if they were aged 19 or older and had sufficient English to complete the surveys. They were sent a web link to complete baseline surveys before or within 6 hours 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 behaviors and attitudes, neighborhood perceptions, individual and household demographics, and residential postal code. Data was collected across four time points: baseline, 1, 3, and 12 months 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 of 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 density of bike lanes, hilliness, destinations, and road connectivity) (Winters et al., 2016)) at home residence. We also include 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 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).

3.0 Results

3.1 Sample characteristics

During the 2016 and 2017 season, 349 people registered in 28 adult bicycle training courses (Figure 1). 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. 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.

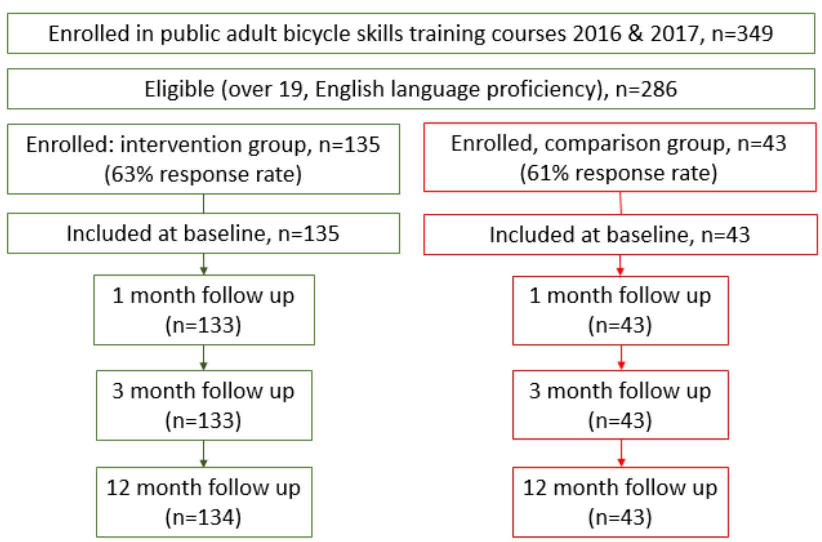

FIGURE 1 Summary of recruitment process

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) 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 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 intervention and comparison groups. Most of participants reported feeling confident knowing 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 3 here]

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.

[TABLE 4 here]

3.3 Regression analysis for bicycling and confidence

We used negative binomial mixed models (Table 5) to assess changes in bicycling over time. 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.

[TABLE 5 here]

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.

[TABLE 6 here]

4.0 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 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 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 hour 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. For example, the Behaviour Change Techniques that were used in the bicycle course (Table 2) focused on teaching skills and knowledge. Reviews have suggested 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 Intervention impact 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

Although the bicycle course was not associated with bicycle commuting changes, 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).

4.1.2 Errands

The course was not associated with changes in errand bicycling, and participants tended to bicycle for errands less frequently than for commuting or leisure. While many of 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). 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

While the course was not associated with longer-term increases in bicycling for leisure, there was a short-term increase. Furthermore, 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). That leisure bicycling affords greater flexibility and is "unconstrained by space or time" (Boyer, 2018, p. 409), is one potential reason city of residence was not associated with leisure bicycling in our results. Another possibility is that participants drove to destinations to ride bicycles. Further investigations, perhaps through qualitative research, may reveal the impact of place on different types of bicycling, or how those bicycling only for leisure may make transitions to transport or errand bicycling.

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. Notably, 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. 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 can 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, and promotional activities 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.

5.0 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. To account for the interest in bicycling, our comparison group consisted of people who enrolled in but did not attend a course. 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. 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 were some overlap between the different “types” of bicycling, especially when trip purposes where combined.

6.0 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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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
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
Hawley & Mackie, 2015, NZ	Evaluation report	Post-intervention retrospective questionnaire; n=86	unclear	# days/month bicycled before course compared to # days/previous month bicycled	Increase
Johnson & Margolis, 2013, UK	Peer-reviewed publication	Pre-post questionnaire; pre n=471, 3 month n=130	3 months	1) # days/previous week bicycling >30 minutes; 2) # days/previous week bicycled to work	1) increase 2) increase
Rissel & 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
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
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
Transport for London, 2016, UK	Evaluation report	Pre-post questionnaire; pre n=800, 3	3 months; 12 months	# days bicycling for	1) increase 2) increase

		month n=258, 12 month n=101		1) commuting, 2) errands, 3) leisure	3) increase
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
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
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 hr/week bicycling target (y/n)	Increase

[a] Sampling strategy included if described in study

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

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) Number, % confident	Comparison (n=43) 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 month	107 (79.9%)	27 (62.8%)	0.04
Can use a map to choose a suitable route for me to bicycle	Intervention	Comparison	
Baseline (% confident)	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 month (% confident)	122 (91.7%)	32 (74.4%)	0.01
Know where safe bike routes are	Intervention	Comparison	
Baseline (% confident)	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 month (% confident)	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

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 (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)**		**0.3 (0.18 – 0.50)**		0.82 (0.61 – 1.12)
Season: Aug-Oct[f]		**0.6 (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								
τ_{00} (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 $_{ID}$
σ^2 (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

Fixed Effects	***I can ride a bicycle safely on a street with cars*** **Base** Odds ratio (95% CI)	**Adjusted** Odds ratio (95% CI)	***I can use a map to choose a suitable route for me to cycle*** **Base** Odds ratio (95% CI)	**Adjusted** Odds ratio (95% CI)	***I know where safe bike routes are*** **Base** Odds ratio (95% CI)	**Adjusted** 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]		0.8 (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						
τ_{00} (Random intercept)	3.29	3.29	3.29	3.29	3.29	3.29
σ^2 (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