*Original Road Safety Research*

# Adolescents' perceptions of long-term effects of cycle skills training

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## Key Findings

- 43% of teens thought cycle skills training (CST) could make them safer in traffic.
- 32% of adolescents reported that CST increased their confidence to cycle to school.
- Adolescents with increased confidence had more favourable attitudes towards CST.
- School support and self-efficacy related to increased cycling confidence after CST.

## Abstract

Cycling to school is uncommon among adolescents in most developed countries. Development of cycling skills through cycle skills training (CST) can reduce cycling-related safety concerns. This study examined long-term effects of CST retrospectively by comparing adolescents' perceptions of cycling to school and their confidence to cycle to school among those who participated in CST in primary and/or intermediate school with non-participants. Adolescents (n=1,260; 51% female; 12 schools) from Dunedin (New Zealand) completed an online survey at school. Adolescents self-reported transport modes to school, perceptions of cycling to school and CST, and previous participation in and perceived benefits of school-based CST programmes. Only 1-2% adolescents usually cycled to school. Overall, 42% agreed CST would make them safer in traffic (no significant difference between CST participants (n=512) and non-participants (n=748)). Among CST participants, 32% reported that CST increased their confidence to cycle to school and those adolescents had more favourable attitudes towards CST than participants who reported no effects. In a multivariable analysis, adolescents' perceptions that CST increased their cycling confidence were positively associated with self-efficacy for cycling to school (odds ratio (OR) (95% confidence interval (CI)): 1.33 (1.07, 1.67)), perceived school support (1.51 (1.01, 2.25)), parental cycling-related safety concerns (1.84 (1.25, 2.69)) and being Māori (6.47 (2.36, 17.7)) or other ethnic origins (2.26 (1.00, 5.10); reference: New Zealand Europeans). Therefore, CST could be a useful strategy to support adolescents' cycling to school, ideally (as suggested in the literature) in combination with appropriate infrastructure changes and speed management measures.

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## Keywords

adolescents, cycling, cycle skills training, attitudes, confidence

## Introduction

Cycling to school has been found to be less common than walking among adolescents in most developed countries, including Australia (Leslie, Kremer, Toumbourou, & Williams, 2010) and New Zealand (Mandic et al., 2017). Rates of cycling to school have declined significantly in recent decades in many high-income countries. New Zealand data show a decline in rates of cycling to secondary schools from 19% in 1989/1990 to 3% in 2010-2014 (Ministry of Transport, 2015). Traffic safety is a key concern regarding cycling for transportation (Department for Transport, 2015; Krizek, Forsyth, & Baum, 2009), especially for children's and adolescents' cycling to school (Hopkins & Mandic, 2017; Mandic, García Bengoechea, Hopkins, Coppell, & Spence, 2022b; Mandic, Hopkins, García Bengoechea, et al., 2020). Children with inadequate cycling skills have previously been found to have much higher crash rates compared with other children, despite cycling less frequently (Preston, 1980). In children, parental confidence in their child's cycling skills is one of the determinants of whether children cycle to school (Ducheyne, De Bourdeaudhuij, Spittaels, & Cardon, 2012; Trapp et al., 2011). In addition, parental perceptions of cycling safety play an important role in influencing cycling habits of adolescents (Carver et al., 2005; Esteban-Cornejo et al., 2016). Therefore, cycling-related traffic safety concerns could be minimised by development of cycling skills (Trapp et al., 2011), combined with appropriate and safe cycling infrastructure, safe routes to school and supportive cycling culture (Rahman, Moore, Smith, Lieswyn, & Mandic, 2020).

Cycle skills training (CST) courses have been designed to help young people develop the skills and confidence to cycle safely in traffic. Most previous research examining the effects of CST has focused on primary school children (Richmond, Zhang, Stover, Howard, & Macarthur, 2014). Intervention studies reported improvements in children's road safety knowledge (McLaughlin & Glang, 2010) and cycling skills (Ducheyne, De Bourdeaudhuij, Lenoir, & Cardon, 2013) after CST. Some studies also reported increased rates of cycling to school and other destinations following CST in children (Mandic, Flaherty, Pocock, et al., 2018; Sersli, De Vries, Gislason, Scott, & Winters, 2019).

Limited research conducted in adolescents showed that both adolescents (Colwell & Culverwell, 2002; Mandic et al., 2016) and their parents (Mandic et al., 2017) believed that CST could improve adolescents' safety when cycling in traffic. A recent study showed that 90-min CST improved cycling skills in adolescents (van Hoef, Kerr, Roth, Brenni, & Endes, 2022). In adolescent girls, a short duration CST improved participants' knowledge of road rules and their confidence to cycle in different environments but did not increase their confidence to cycle to school or improve rates of cycling to school (Mandic, Flaherty, Ergler, et al., 2018).

Although most previous research showed that CST improved children's and adolescents' cycling-related knowledge, confidence and skills in the short term, long-term effects of CST remain largely unknown. In two studies, improvements in children's cycling skills were maintained for five months (Ducheyne, De Bourdeaudhuij, Lenoir, & Cardon, 2013) and two years after the training (Savill, Bryan-Brown, & Harland, 1996). However, not all studies found improvements in children's knowledge and cycle skills following a CST programme (Macarthur, Parkin, Sidky, & Wallace, 1998). In addition, a systematic review found that participation in CST did not seem to translate into reduced injury rates or improved cycle skills nor improved attitudes towards safe cycling in young people (Richmond et al., 2014). Moreover, no previous research examined the effects of multiple exposures to CST during childhood on adolescents' attitudes towards CST and perceived benefits of previous participation in CST programme(s). To extend the current knowledge, this study retrospectively examined the long-term effects of CST by comparing adolescents' perceptions of cycling to school and their confidence to cycle to school among those who participated in such training in primary and/or intermediate school compared with non-participants. This study also examined correlates of adolescents' perceptions that participation in CST in primary and/or intermediate school increased their confidence to cycle to secondary school among adolescents who lived within a reasonable cycling distance from their school (up to 4 km).

## Method

A total of 1,828 adolescents from all twelve secondary schools in Dunedin (New Zealand) participated in the Built Environment and Active Transport to School (BEATS) Natural Experiment in 2020-2022 (Mandic, Hopkins, García Bengoechea, et al., 2020). Details on participant recruitment and study procedures have been published elsewhere (Mandic, Hopkins, García Bengoechea, et al., 2020). Briefly, adolescents received information through their school and if interested signed written consent prior to participation. Parental consent was not required. The research protocol was approved by the University of Otago Human Ethics Committee (17/188) and Auckland University of Technology Ethics Committee (21/314). After excluding participants with missing or invalid consent (n=10), missing survey data (n=19), an invalid survey (e.g., invalid survey responses; n=4), those boarding at school or privately (n=283), lacking cycle skills training-related survey data (n=240), and adolescents who reported

participating in CST in secondary school (n=62), 1,260 participants were included in this research.

Adolescents completed an online survey during school time under supervision of research staff. Participants self-reported their sociodemographic characteristics (age, gender, ethnicity), home address, usual modes of transport to school, perceptions of cycling to school and CST, and previous participation in a school-based CST programme. Home-to-school distance was calculated using Google Maps using the shortest path distance. A threshold of up to 4 km for reasonable distance for adolescents' cycling to school was based on previous research (Nelson, Foley, O'Gorman, Moyna, & Woods, 2008). Usual mode(s) of transport to school and categorisation of adolescents into 'active', 'motorised' and 'mixed' transport users were determined based on transport mode(s) that adolescents used 'most of the time' or 'all of the time', as described elsewhere (Mandic et al., in review, 2022a; Mandic et al., 2017). Adolescents also self-reported the number of days they cycled to and from school in the previous week. Perceptions of cycling to school were assessed using questions guided by the Theory of Planned Behaviour, as published elsewhere (Mandic et al., 2022b). Briefly, perceptions of cycling to school included attitudes, subjective norm, perceived behavioural control, behavioural intentions, environmental barriers, perceptions of the route to school and safety perceptions. In addition, adolescents also reported attitudes towards, and social support for, cycling in general.

Attitudes towards CST were assessed with two survey items, "Cycle skills training could make me safer in traffic" and "I would take cycle skills training if it was available at my school", using a 4-point Likert scale, as described previously (Mandic et al., 2016). The questionnaire included a CST definition: "Cycle skills training is a short interactive course that teaches road awareness and how to cycle on the road". In the current study, participants also reported whether they participated in a CST programme at school (primary (aged 5-10 years), intermediate (11-12 years) and/or secondary (13-18 years)) and whether the CST programme made them feel differently about cycling to school (response categories: 'Yes, I became more confident to cycle to school'; 'Yes, I became less confident to cycle to school'; 'Yes for another reason. Please specify"; 'No'). Due to the small number of responses in the total sample, response categories, 'Yes, I became less confident to cycle to school' (6 responses) and 'Yes for another reason" (17 responses), were excluded from detailed analysis of perceived benefits of CST.

Continuous variables are reported as mean ±SD whereas categorical variables are reported as frequency (percentage). Differences between the groups were compared using $\chi^2$ tests for categorical variables and t-tests for independent samples or ANOVA for continuous variables with Scheffé post-hoc comparisons (or Mann-Whitney U-test or ANOVA with Tamhane's T2 when the variances were unequal). Given that distance to school is the strongest correlate of active transport to school (Ikeda et al., 2018) and that adolescents' and their parents' perceptions of cycling to school differ by how far adolescents live from their school (Mandic et al., 2022b; Mandic, Hopkins, García Bengoechea, et al., 2020), factors related to increased confidence for cycling to school after CST were examined using binary logistic regression among the 555 adolescents who lived within 4 km from their school. Significant univariate correlates were entered into a multivariable model. P-level of less than 0.05 was considered statistically significant. Data were analysed using SPSS Statistical Package, V 27.0.

## Results

Adolescents were on average 14.9±1.3 years old (50.7% females; 65.9% New Zealand European ethnicity) (Table 1). In the total sample, 57.6% of adolescents had two or more bicycles at home, 79.0% lived in households with two or more vehicles, 44.3% lived within 4 km from their school and 17.7% relied on active transport to school (15.6% on foot; 1.0% by bicycle; 0.6% other active modes) (Table 1). In the previous week, 96.9% of adolescents never cycled to or from school and the remaining 3.1% reported cycling to or from school on average on 2.7±1.4 out of five days.

Overall, 512 (40.6%) had participated in school-based CST (220 in primary, 139 in intermediate and 153 in both primary and intermediate schools) whereas 748 (59.4%) were 'non-participants' (Table 1). Compared with non-participants, CST participants lived in households with a greater proportion of two or more vehicles and more frequently used active transport to school (but with similar proportion of adolescents cycling to school (1.0% and 1.1%)). Other sociodemographic characteristics of CST participants did not differ significantly from non-participants.

In the total sample, 42.9% of adolescents agreed CST would make them safer to cycle in traffic, with no significant difference by participation in CST training, timing of CST programme (in primary and/or intermediate school), gender, ethnicity, or living within versus beyond cycling distance to school (Table 2). Overall, 19.8% agreed they would take CST at their school with no significant difference between the CST participants versus non-participants or by timing of the CST training (data not presented).

Among CST participants, 32.2% of adolescents in the total sample reported that CST made them feel more confident to cycle to school, 1.2% reported less confidence, 3.3% reported other benefits from CST, and 63.3% reported no effects. The proportion of adolescents who reported that CST made them more confident to cycle to school did not differ significantly by exposure to CST in primary and/or intermediate school (primary: 33.2%; intermediate: 28.2%; primary and intermediate: 38.9%; p=0.195) nor by living

**Table 1. Sociodemographic characteristics of study participants in the total sample**

| | **Total sample** (n=1260) | **Had cycle skills training** (n=512) | **Did not have cycle skills training** (n=748) | **p-value** |
|---|---|---|---|---|
| **Age (years)** | 14.9 ± 1.3 | 14.8 ± 1.3 | 14.9 ± 1.3 | .082 |
| **Gender [n (%)]** | (n=1260) | (n=512) | (n=748) | |
| Male | 582 (46.2) | 240 (46.9) | 342 (45.7) | |
| Female | 639 (50.7) | 259 (50.6) | 380 (50.8) | |
| Gender diverse | 39 (3.1) | 13 (2.5) | 26 (3.5) | .621 |
| **Ethnicity [n (%)]** | (n=1260) | (n=512) | (n=748) | |
| New Zealand European | 830 (65.9) | 346 (67.6) | 484 (64.7) | |
| Māori | 182 (14.4) | 71 (13.9) | 111 (14.8) | |
| Other | 248 (19.7) | 95 (18.6) | 153 (20.5) | .566 |
| **Number of bicycles available to use to get to school [n (%)]** | (n=1260) | (n=512) | (n=748) | |
| None | 296 (23.5) | 106 (20.7) | 190 (25.4) | |
| One | 238 (18.9) | 101 (19.7) | 137 (18.3) | |
| Two or more | 726 (57.6) | 305 (59.6) | 421 (56.3) | .154 |
| **Number of vehicles at home [n (%)]** | (n=1260) | (n=512) | (n=748) | |
| None | 19 (1.5) | 9 (1.8) | 10 (1.3) | |
| One | 246 (19.5) | 82 (16.0) | 164 (21.9) | |
| Two or more | 995 (79.0) | 421 (82.2) | 574 (76.7) | .031 |
| **Distance to school [n (%)]** | (n=1254) | (n=510) | (n=744) | |
| Within cycling distance (≤4.0 km) | 555 (44.3) | 236 (46.3) | 319 (42.9) | |
| Beyond cycling distance (>4.0 km) | 699 (55.7) | 274 (53.7) | 425 (57.1) | .234 |
| **Transport to school [n (%)]** | (n=1222) | (n=497) | (n=725) | |
| Active | 216 (17.7) | 109 (21.9) | 107 (14.8) | |
| Motorised | 694 (56.8) | 255 (51.3) | 439 (60.6) | |
| Mixed | 312 (25.5) | 133 (26.8) | 179 (24.7) | .001 |

**Table 2. Adolescents' perceptions of cycle skills training**

| | | Cycle skills training could make me safer in traffic | | | | |
|---|---|---|---|---|---|---|
| | **n** | **Strongly agree** | **Agree** | **Disagree** | **Strongly disagree** | **p-value** |
| **Total sample [n (%)]** | 1260 | 147 (11.7) | 393 (31.2) | 290 (23.0) | 430 (34.1) | - |
| **CST participation [n (%)]** | | | | | | |
| CST participants | 512 | 55 (10.7) | 161 (31.4) | 119 (23.2) | 177 (34.6) | |
| Non-participants | 748 | 92 (12.3) | 232 (31.0) | 171 (22.9) | 253 (33.8) | .869 |
| **Previous cycle skills training at school [n (%)]** | | | | | | |
| Yes, in primary school only | 220 | 21 (9.5) | 71 (32.3) | 50 (22.7) | 78 (35.5) | |
| Yes, in intermediate school only | 139 | 19 (13.7) | 41 (29.5) | 29 (20.9) | 50 (36.0) | |
| Yes, both in primary and intermediate school | 153 | 15 (9.8) | 49 (32.0) | 40 (26.1) | 49 (32.0) | |
| No | 748 | 92 (12.3) | 232 (31.0) | 171 (22.9) | 253 (33.8) | .930 |
| **Gender [n (%)]** | | | | | | |
| Male | 582 | 68 (11.7) | 165 (28.4) | 139 (23.9) | 210 (36.1) | |
| Female | 639 | 71 (11.1) | 219 (34.3) | 149 (23.3) | 200 (31.3) | .133 |
| **Ethnicity [n (%)]** | | | | | | |
| New Zealand European | 830 | 89 (10.7) | 253 (30.5) | 198 (23.9) | 290 (34.9) | |
| Māori | 182 | 24 (13.2) | 46 (25.3) | 42 (23.1) | 70 (38.5) | |
| Other | 248 | 34 (13.7) | 94 (37.9) | 50 (20.2) | 70 (28.2) | .052 |
| **Distance to school [n (%)]** | | | | | | |
| Within cycling distance (≤4.0 km) | 555 | 53 (9.5) | 181 (32.6) | 119 (21.4) | 202 (36.4) | |
| Beyond cycling distance (>4.0 km) | 699 | 93 (13.3) | 208 (29.8) | 171 (24.5) | 227 (32.5) | .067 |

CST = Cycle skills training.

within versus beyond cycling distance to school (33.0% vs. 34.2%; p=0.781).

Sociodemographic characteristics of CST participants and non-participants who lived within a reasonable cycling distance to their school (up to 4 km) are presented in Table 3. Compared with non-participants, CST participants had higher levels of subjective norms and self-efficacy for cycling to school and less frequently reported environmental barriers, safety concerns and convenience of trip-chaining for school transport (Table 4), with most of the significant differences being between adolescents who participated in CST in both primary and intermediate schools versus non-participants (data presented in Appendix). Adolescents' attitudes towards cycling in general and CST and their interest in CST uptake at school did not differ between CST participants versus non-participants nor by the timing of exposure to CST (see Appendix).

Among CST participants who lived within 4 km from their school, 31.8% reported increased confidence to cycle to school after CST whereas 64.4% reported no difference. Compared with their peers who did not report benefits from CST, CST participants who reported increased confidence to cycle to school had a higher proportion of Māori or other ethnic groups (compared with New Zealand European) (Table 3); expressed more favourable beliefs about cycling to school; and reported more frequently enjoyment of cycling for recreation, self-efficacy for cycling to school, behavioural intentions to cycle to school, school's encouragement and parental safety concerns related to cycling to school (Table 4). In addition, twice as many adolescents who reported increased confidence of cycling to school after CST agreed that CST could make them safer in traffic and that they would take CST if offered at their high school (Figure 1). In a multivariable analysis, adjusted for age and gender, adolescents'

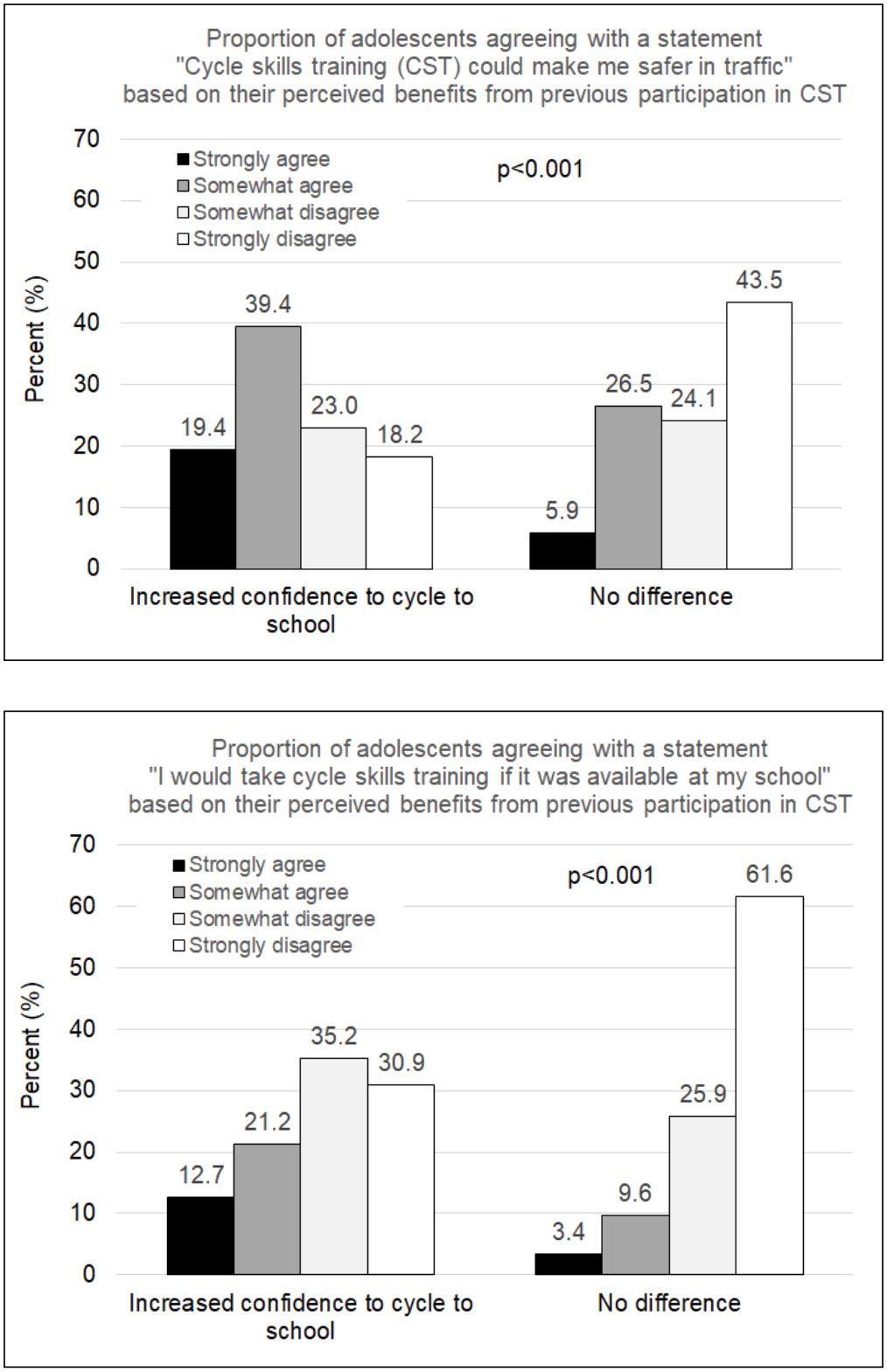


**Figure 1. Adolescents' perceptions of cycle skills training being able to make them safer in traffic (top) and their interest in taking such training at their school (bottom) based on their perceived benefits from previous participation in cycle skills training at primary and/or intermediate school**

**Table 3. Sociodemographic characteristics of study participants who lived within 4 km from their school by cycle skills training participation and perceived benefits**

| | **Previous participation in cycle skills training** | | | **Has cycle skills training made you feel differently about cycling to school? (in CST participants only)** | | |
|---|---|---|---|---|---|---|
| | **Yes** (n=236) | **No** (n=319) | **p-value** | **Became more confident** (n=75) | **No effect** (n=152) | **p-value** |
| **Age (years)** | 14.7 ± 1.2 | 15.0 ± 1.4 | .019 | 14.7 ± 1.3 | 14.7 ± 1.1 | .904 |
| **Gender [n (%)]** | (n=236) | (n=319) | | (n=75) | (n=152) | |
| Male | 120 (50.8) | 149 (46.7) | | 38 (50.7) | 80 (52.6) | |
| Female | 111 (47.0) | 161 (50.5) | | 37 (49.3) | 68 (44.7) | |
| Gender diverse | 5 (2.1) | 9 (2.8) | .585 | 0 (0.0) | 4 (2.6) | .326 |
| **Ethnicity [n (%)]** | (n=236) | (n=319) | | (n=75) | (n=152) | |
| New Zealand European | 159 (67.4) | 196 (61.4) | | 41 (54.7) | 113 (74.3) | |
| Māori | 31 (13.1) | 49 (15.4) | | 15 (20.0) | 14 (9.2) | |
| Other | 46 (19.5) | 74 (23.2) | .355 | 19 (25.5) | 25 (16.4) | .009 |
| **Number of bicycles available to use to get to school [n (%)]** | (n=236) | (n=319) | | (n=75) | (n=152) | |
| None | 45 (19.1) | 95 (29.8) | | 13 (17.3) | 31 (20.4) | |
| One | 58 (24.6) | 55 (17.2) | | 17 (22.7) | 17 (25.7) | |
| Two or more | 133 (56.4) | 169 (53.0) | .007 | 45 (60.0) | 82 (53.9) | .686 |
| **Number of vehicles at home [n (%)]** | (n=236) | (n=319) | | (n=75) | (n=152) | |
| None | 8 (3.4) | 8 (2.5) | | 3 (4.0) | 5 (3.3) | |
| One | 47 (19.9) | 81 (25.4) | | 13 (17.3) | 32 (21.1) | |
| Two or more | 181 (76.7) | 230 (72.1) | .284 | 59 (78.7) | 115 (75.7) | .786 |
| **Distance to school (km)** | 1.9 ± 1.1 | 2.3 ± 1.0 | <.001 | 1.9 ± 1.1 | 1.9 ± 1.1 | .448 |
| **Transport to school [n (%)]** | (n=228) | (n=311) | | (n=72) | (n=149) | |
| Active | 106 (46.5) | 100 (32.2) | | 39 (54.2) | 65 (43.6) | |
| Motorised | 80 (35.1) | 146 (46.9) | | 21 (29.2) | 57 (38.3) | |
| Mixed | 42 (18.4) | 65 (20.9) | .003 | 12 (16.7) | 27 (18.1) | .310 |

CST = Cycle skills training.

**Table 4. Attitudes towards cycling in general and cycling to school among adolescents who lived within 4 km from their school by cycle skills training participation and perceived benefits**

| | Previous participation in cycle skills training | | | Has cycle skills training made you feel differently about cycling to school? (in CST participants only) | | |
|---|---|---|---|---|---|---|
| | Yes (n=236) | No (n=319) | p-value | Became more confident (n=75) | No effect (n=152) | p-value |
| **Cycling in general:** | | | | | | |
| Attitudes towards cycling in general | (n=236) | (n=319) | | (n=75) | (n=152) | |
| I like bike riding for recreational purposes* | 2.3 ± 1.1 | 2.2 ± 1.1 | .629 | 2.7 ± 1.0 | 2.0 ± 1.0 | <.001 |
| **Social support for cycling in general** | (n=236) | (n=319) | | (n=75) | (n=152) | |
| One or both of my parents or guardians cycle frequently | 2.2 ± 1.9 | 2.0 ± 1.8 | .261 | 2.2 ± 1.9 | 2.1 ± 1.8 | .832 |
| I often cycle with my parents* | 1.7 ± 0.9 | 1.8 ± 1.0 | .298 | 1.8 ± 0.9 | 1.6 ± 0.9 | .307 |
| I often cycle with my friends* | 1.5 ± 0.7 | 1.6 ± 0.9 | .550 | 1.6 ± 0.7 | 1.5 ± 0.7 | .067 |
| **Cycling to school:** | | | | | | |
| **Attitudes towards cycling to school** | (n=236) | (n=319) | | (n=75) | (n=152) | |
| Experiential beliefs (cycling to school is interesting/ pleasant/ stimulating) (1=low to 7=high) | 4.1 ± 1.7 | 4.0 ± 1.7 | .439 | 4.7 ± 1.6 | 3.9 ± 1.8 | .001 |
| Instrumental beliefs (cycling to school is healthy/good/useful) (1=low to 7=high) | 4.9 ± 1.5 | 5.0 ± 1.5 | .761 | 5.4 ± 1.3 | 4.7 ± 1.5 | .001 |
| **Social support for cycling to school** | (n=236) | (n=319) | | (n=75) | (n=152) | |
| Subjective norm (parents/peers think I should cycle) (1=low to 7=high) | 3.5 ± 1.7 | 3.1 ± 1.7 | .012 | 3.3 ± 1.5 | 3.5 ± 1.8 | .448 |
| It is not cool to cycle to school* | 2.0 ± 1.0 | 2.0 ± 1.0 | .900 | 1.9 ± 0.9 | 2.0 ± 1.0 | .286 |
| My school encourages me to cycle to school* | 1.7 ± 0.8 | 1.7 ± 0.8 | .602 | 1.9 ± 0.9 | 1.6 ± 0.8 | .009 |
| **Perceived behavioural control for cycling to school** | | | | | | |
| **Control** | (n=236) | (n=319) | | (n=75) | (n=152) | |
| I have complete control over whether or not I cycle to school | 5.6 ± 1.9 | 5.2 ± 2.1 | .054 | 5.3 ± 1.9 | 5.7 ± 1.8 | .110 |
| **Self-efficacy** | (n=236) | (n=319) | | (n=75) | (n=152) | |
| Confidence/ability/capability composite score for cycling (1=low to 7=high) | 5.0 ± 2.1 | 4.4 ± 2.2 | .001 | 5.6 ± 1.8 | 4.8 ± 2.2 | .009 |
| **Convenience** | (n=236) | (n=319) | | (n=75) | (n=152) | |
| It is easier for someone to drive me to school, on the way to something else* | 2.4 ± 1.2 | 2.7 ± 1.2 | .003 | 2.5 ± 1.1 | 2.3 ± 1.2 | .458 |

| | Previous participation in cycle skills training | | | Has cycle skills training made you feel differently about cycling to school? (in CST participants only) | | |
|---|---|---|---|---|---|---|
| | **Yes** (n=236) | **No** (n=319) | **p-value** | **Became more confident** (n=75) | **No effect** (n=152) | **p-value** |
| **Perceived behavioural control for cycling to school (continued)** | | | | | | |
| **Environmental barriers** | (n=236) | (n=319) | | (n=75) | (n=152) | |
| It is too far to cycle to school* | 1.7 ± 0.6 | 2.0 ± 1.0 | .002 | 1.7 ± 0.8 | 1.7 ± 0.9 | .933 |
| There are no cycle lanes along the way* | 2.7 ± 1.1 | 2.7 ± 1.1 | .762 | 2.6 ± 1.1 | 2.7 ± 1.1 | .399 |
| The weather is too cold and wet to cycle to school* | 2.6 ± 1.0 | 2.7 ± 1.0 | .134 | 2.6 ± 1.0 | 2.6 ± 1.1 | .817 |
| **Behavioural intentions for cycling to school** | (n=236) | (n=319) | | (n=75) | (n=152) | |
| Behavioural intentions for cycling to school (I want/intend to regularly cycle to school (1=low to 7=high) | 1.9 ± 1.4 | 1.8 ± 1.4 | .611 | 2.2 ± 1.5 | 1.7 ± 1.2 | <.001 |
| **Perceptions of the route to school** | (n=236) | (n=319) | | (n=75) | (n=152) | |
| There are too many hills along the way* | 2.0 ± 1.1 | 2.5 ± 1.1 | <.001 | 1.9 ± 1.0 | 2.0 ± 1.2 | .423 |
| There is too much traffic along the route* | 2.0 ± 1.0 | 2.2 ± 1.1 | .075 | 2.1 ± 1.0 | 2.0 ± 1.0 | .236 |
| There is one or more dangerous crossings along the route* | 2.0 ± 1.0 | 2.2 ± 1.1 | .026 | 2.1 ± 1.0 | 1.9 ± 1.0 | .079 |
| **Safety perceptions of cycling to school** | (n=236) | (n=319) | | (n=75) | (n=152) | |
| It is unsafe to cycle to school* | 2.1 ± 1.0 | 2.3 ± 1.0 | .013 | 2.1 ± 1.0 | 2.0 ± 1.0 | .735 |
| My parents think it is not safe to cycle to school* | 1.8 ± 1.0 | 2.1 ± 1.0 | <.001 | 2.0 ± 1.0 | 1.7 ± 0.9 | .027 |
| **Attitudes towards cycle skills training** | (n=236) | (n=319) | | (n=75) | (n=152) | |
| Cycle skills training could make me safer in traffic* | 2.1 ± 1.0 | 2.2 ± 1.1 | .113 | 2.6 ± 1.0 | 1.8 ± 0.9 | <.001 |
| I would take cycle skills training if it was available at my school* | 1.7 ± 0.9 | 1.7 ± 0.9 | .708 | 2.1 ± 1.0 | 1.5 ± 0.8 | <.001 |

Data collected using a 7-point Likert scale (1=strongly agree to 7=strongly disagree, unless indicated otherwise)
*Data collected on a 4-point Likert scale (1=strongly disagree to 4=strongly.

**Table 5. Multivariable correlates of adolescents' perception that cycle skills training increased their confidence to cycle to school among adolescents who lived within 4 km from their school**

| | B | S.E. | p-value | OR | 95% Confidence interval | |
|---|---|---|---|---|---|---|
| | | | | | Lower | Upper |
| Age | 0.00 | 0.14 | .998 | 1.00 | 0.76 | 1.32 |
| Gender (Ref. male) | -0.50 | 0.36 | .164 | 0.61 | 0.30 | 1.23 |
| Ethnicity (Ref. New Zealand European) | | | | | | |
| Māori | 1.87 | 0.52 | <.001 | 6.47 | 2.36 | 17.74 |
| Other | 0.82 | 0.42 | .049 | 2.26 | 1.00 | 5.10 |
| I like bike riding for recreational purposes | 0.34 | 0.18 | .063 | 1.40 | 0.98 | 2.01 |
| Experiential beliefs for cycling to school (cycling to school is interesting/ pleasant/ stimulating) (1=low to 7=high) | 0.16 | 0.15 | .300 | 1.17 | 0.87 | 1.59 |
| Instrumental beliefs for cycling to school (cycling to school is healthy/good/useful) (1=low to 7=high) | 0.02 | 0.19 | .917 | 1.02 | 0.71 | 1.48 |
| My school encourages me to cycle to school | 0.41 | 0.20 | .046 | 1.51 | 1.01 | 2.25 |
| Self-efficacy: Confidence/ability/capability composite score for cycling to school | 0.28 | 0.11 | .010 | 1.33 | 1.07 | 1.65 |
| Behavioural intentions for cycling to school (I want/ intend to regularly cycle to school) | 0.07 | 0.13 | .575 | 1.07 | 0.84 | 1.37 |
| My parents think it is not safe to cycle to school | 0.61 | 0.20 | .002 | 1.84 | 1.25 | 2.69 |

B = Beta coefficient; S.E. = Standard error; OR = Odds ratio. Model statistics: Nagelkerke R square = 0.296.

perceptions that CST increased their confidence to cycle to school were positively associated with self-efficacy for cycling to school; perceived school support; parental cycling-related safety concerns; and being Māori or other ethnic groups (compared with New Zealand Europeans) (Table 5).

## Discussion

Key findings from this study are:

1. 43% of adolescents agreed that CST could make them safer in traffic irrespective of whether they previously participated in the CST programme(s);
2. 32% of CST participants reported increased confidence to cycle to school due to exposure to CST in primary and/or intermediate school;
3. Among adolescents living within 4 km from their school, positive correlates of adolescents' perceptions that CST increased their cycling to school confidence were self-efficacy for cycling to school, perceived school support, parental cycling-related safety concerns and being Māori or belonging to other ethnic groups (compared with New Zealand Europeans); and
4. Twice as many adolescents who reported increased confidence to cycle to school following CST perceived that CST could make them safer in traffic and were interested in taking such training at school compared with their counterparts. These findings suggest that CST could be a useful strategy to improve adolescents' confidence and positive attitudes towards cycling to school.

In this study, 44% of adolescents perceived that CST could make them safer in traffic, which is consistent with previous research (Mandic et al., 2016, Colwell and Culverwell, 2002). Our previous work showed that adolescents' enjoyment of cycling for recreation, their desire to cycle to school, perceiving cycling to school as useful, frequently cycling with parents and being encouraged by their school to cycle to school were related to adolescents' perceptions that CST could make them safer in traffic (Mandic et al., 2016). This study extends current knowledge by demonstrating that adolescents' attitudes toward CST did not differ based on the timing of their exposure to CST in primary and/or intermediate school. However, in the present study, one in three adolescents who participated in CST in primary and/or intermediate school reported increased confidence in cycling to high school as a result of CST training, irrespective of the timing of the exposure to CST and those adolescents had more favourable attitudes towards CST in high school compared with their counterparts. Therefore, it is essential that future CST programmes facilitate positive

experiences and increase children's confidence to cycle to school. In addition, future initiatives should make the most of adolescents' positive attitudes towards CST to further raise awareness of benefits of such programmes, tailor future CST programmes to adolescents' needs (Mandic, Flaherty, Ergler, et al., 2018) and potentially offer CST programmes in secondary schools.

Compared with non-participants, CST participants (particularly those who participated in CST in both primary and intermediate schools) reported higher self-efficacy for cycling to school. Nevertheless, the rates of cycling to school in this study were low (1%; which is representative of the city where this study was conducted (Mandic et al., 2022a)) and did not differ between CST participants versus non-participants. These findings reinforce the importance of other factors on whether adolescents cycle to school including distance to school, social support, cultural norms, environmental factors and perceived safety of cycling (Carver et al., 2005; Hopkins & Mandic, 2017; Mandic et al., 2022b), particularly in cities with low rates of cycling to school (Frater et al., 2017). Supportive social and physical environments in home and school neighbourhoods (Ikeda et al., 2018; Rahman, Moore, & Mandic, 2022) and presence of safe routes for cycling to school (Rahman, Pocock, Moore, & Mandic, 2020) are especially important for adolescents in countries like New Zealand, where approximately 40% of children (Mandic, Flaherty, Pocock, et al., 2018) - but only 10% of adolescents (Mandic, Flaherty, Ergler, et al., 2018) - expressed preference and intention to cycle to school.

Among CST participants who lived within 4 km from their school, positive correlates of adolescents' perceptions that CST increased their cycling to school confidence were self-efficacy for cycling to school, perceived school support, parental cycling-related safety concerns and being Māori and other ethnic groups (compared with New Zealand Europeans). Although these findings are based on a retrospective analysis, this is the first study to examine the long-term effects of exposure to CST in primary and/or intermediate school on adolescents' confidence to cycle to school. The findings indicate that CST may be particularly beneficial for children whose parents report stronger safety concerns about cycling to school. Interestingly, the findings also suggest that children with higher cycling self-efficacy may be able to make the most of school-based CST. The findings also illustrate the important role schools may play as a setting for the promotion of habits related to physical activity and sustainable travel behaviour (ISPAH, 2020). In addition, the findings emphasise that CST programmes may be particularly beneficial for Māori adolescents and other minority ethnic groups compared to New Zealand Europeans. These findings reinforce the notion that school-based CST may be of greater benefit to vulnerable and hard-to-reach groups, which are often the least physically active. Thus, in combination with other actions, CST could be a useful strategy to achieve the principle of 'proportional universality' advocated in the Global Action Plan on Physical Activity (WHO, 2018). Finally, the results suggest that further exposure to CST in secondary schools may be warranted to build on and reinforce the beneficial effects gained through the CST programmes in primary and/or intermediate school.

To be both safe and effective, CST programmes should be only one component of the comprehensive efforts to support cycling to school and need to be complemented by actual infrastructure changes and speed management measures. Recent best practice guidance from the World Health Organization (WHO) confirms that infrastructure is key to increasing active travel, particularly road and intersection design, travel speeds, and mode separation – particularly for young and other safety-concerned cyclists (WHO, 2022). This accords with the 'Vision Zero' approach to reducing travel crash fatalities, which is based on a socio-technical approach, in contrast to the road user focus traditionally used in most countries (Larsson et al., 2010). The WHO also recommends promoting active travel to school by combining infrastructure improvements and enforcement with safety education and incentives for active travel (WHO, 2022). Research conducted with New Zealand adolescents and parents showed that a complex range of factors contributes to perceptions of safety of cycling to school, including features and perceptions of the built environment and traffic safety in addition to adolescents' cycling skills and their previous cycling experiences (including crashes) (Hopkins and Mandic, 2017) and that cycling-related safety concerns increase with increasing distance to school (Mandic et al., 2020; Mandic et al., 2022b). Therefore, minimising parental and adolescents' concerns regarding safety of cycling through supportive infrastructure and speed management measures in the home and school neighbourhoods and along the school routes are essential for supporting the CST programmes and facilitating behaviour change and mode shift in the long term.

Study strengths include a large representative sample of adolescents from all secondary schools in one city and delineation of CST programme exposure in primary, intermediate, or both primary and intermediate schools.

## Study Limitations

Study limitations include cross-sectional study design with retrospective analysis and data collection in one city with low rates of adolescents' cycling to school which may limit generalisability of findings to other geographical locations and our ability to examine differences among participants based on cycling status, and precludes comparisons of before and after transport mode share and cycling rates for school-age children. In addition, this research did not collect data on actual crashes/injuries or near-misses reported by adolescents. More research, using prospective designs, is needed to ascertain the long-term effects of

CST in young people, including data collection on mode of transport to school and cycling rates before and after CST in primary, intermediate and high schools as well as collecting data on actual crashes/injuries or near-misses experienced by study participants.

## Conclusions

Two out of five adolescents thought CST could make them safer in traffic. One in three CST participants reported increased confidence in cycling to school due to their participation in CST in primary and/or intermediate school. Those adolescents also had more favourable attitudes towards CST in high school compared to their counterparts. Higher levels of self-efficacy for cycling to school, school support, parental safety concerns and ethnicity were positive correlates of adolescents' perceptions that CST increased their confidence to cycle to school. Despite the limitations of the available data, the findings suggest that CST could be a useful strategy to improve adolescents' confidence to cycle to school and their attitudes towards cycling to school. More research, using prospective designs, is needed to ascertain the long-term effects of CST. To be safe and effective, CST programmes would ideally be complemented by infrastructure changes and speed management measures and be further evaluated in term of crash, death and injury outcomes.

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## Author Contributions

Sandra Mandic: Conceptualisation, data curation, formal analysis, funding acquisition, investigation, methodology, project administration, resources, supervision, visualisation, writing – original draft, writing – review & editing. Charlotte Flaherty: Conceptualisation, methodology, data collection, writing – review & editing. Jennifer S. Mindell: Conceptualisation, writing – review & editing. Enrique García Bengoechea: Conceptualisation, formal analysis, funding acquisition, methodology, writing – review & editing. All authors have read and agreed to the published version of the manuscript.

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## Human Research Ethics Review

All subjects gave their informed consent for inclusion before they participated in the study. The study was conducted in accordance with the Declaration of Helsinki, and the protocol was approved by the University of Otago Human Ethics Committee (17/188).

## Data Availability Statement

Data used in data analysis for this project will not be shared due to the sensitivity of the collected data as well as participants having been given assurances that the collected data will not be shared.

## Conflicts of interest

Sandra Mandic is the founder and the director of the research consultancy AGILE Research Ltd. (www.agileresearch.nz) and Principal Advisor Transport Strategy at Wellington City Council (Wellington, New Zealand). Other authors have no conflict of interest.

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## Appendix

**Supplementary Table. Attitudes towards cycling in general and cycling to school among adolescents who lived within 4 km from their school by timing of cycle skills training participation**

| | **Timing of previous cycle skills training** | | | | |
|---|---|---|---|---|---|
| | **Yes, in primary school** (n=91) | **Yes, in intermediate school** (n=66) | **Yes, in both primary and intermediate school** (n=79) | **No cycle skills training** (n=319) | **p-value** |
| **Cycling in general** | | | | | |
| **Attitudes towards cycling in general** | | | | | |
| I like bike riding for recreational purposes* | 2.3 ± 1.0 | 2.3 ± 1.1 | 2.1 ± 1.0 | 2.2 ± 1.1 | .566 |
| **Social support for cycling in general** | | | | | |
| One or both of my parents or guardians cycle frequently | 2.3 ± 1.9 | 2.0 ± 1.6 | 2.3 ± 2.1 | 2.0 ± 1.8 | .463 |
| I often cycle with my parents* | 1.8 ± 1.0 | 1.6 ± 0.8 | 1.7 ± 0.9 | 1.8 ± 1.0 | .368 |
| I often cycle with my friends* | 1.6 ± 0.8 | 1.5 ± 0.7 | 1.5 ± 0.7 | 1.6 ± 0.9 | .323 |
| **Cycling to school** | | | | | |
| **Attitudes towards cycling to school** | | | | | |
| Experiential beliefs (cycling to school is interesting/ pleasant/ stimulating) (1=low to 7=high) | 3.9 ± 1.8 | 4.2 ± 1.7 | 4.3 ± 1.7 | 4.0 ± 1.7 | .417 |
| Instrumental beliefs (cycling to school is healthy/ good/useful) (1=low to 7=high) | 4.8 ± 1.6 | 5.1 ± 1.3 | 5.0 ± 1.4 | 5.0 ± 1.5 | .788 |

| | Timing of previous cycle skills training | | | | |
|---|---|---|---|---|---|
| | **Yes, in primary school** (n=91) | **Yes, in intermediate school** (n=66) | **Yes, in both primary and intermediate school** (n=79) | **No cycle skills training** (n=319) | **p-value** |
| **Social support for cycling to school** | | | | | |
| Subjective norm (parents/peers think I should cycle) (1=low to 7=high) | 3.2 ± 1.5 | 3.6 ± 1.7 | 3.7 ± 1.8 | 3.1 ± 1.7 | .015 |
| It is not cool to cycle to school* | 2.3 ± 1.0 [c] | 2.0 ± 1.0 | 1.7 ± 0.8 [a] | 2.0 ± 1.0 | .003 |
| My school encourages me to cycle to school* | 1.8 ± 0.9 | 1.7 ± 0.9 | 1.7 ± 0.8 | 1.7 ± 0.8 | .829 |
| **Perceived behavioural control for cycling to school** | | | | | |
| **Control** | | | | | |
| I have complete control over whether or not I cycle to school | 5.4 ± 1.9 | 5.6 ± 2.1 | 5.8 ± 1.7 | 5.2 ± 2.1 | .093 |
| **Self-efficacy** | | | | | |
| Confidence/ability/capability composite score for cycling (1=low to 7=high) | 4.6 ± 2.1 | 5.1 ± 2.3 | 5.5 ± 1.8 [d] | 4.4 ± 2.2 [c] | <.001 |
| **Convenience** | | | | | |
| It is easier for someone to drive me to school, on the way to something else* | 2.5 ± 1.2 | 2.4 ± 1.2 | 2.2 ± 1.2 [d] | 2.7 ± 1.2 [c] | .005 |

[a] $p<0.05$ vs. yes, in primary school; [b] $p<0.05$ vs yes, in intermediate school; [c] $p<0.05$ vs. yes, in primary and intermediate school; [d] $p<0.05$ vs. no cycle skills training.

Data collected using a 7-point Likert scale (1=strongly agree to 7=strongly disagree, unless indicated otherwise)
*Data collected on a 4-point Likert scale (1=strongly disagree to 4=strongly.

**Supplementary table. (Continued) Attitudes towards cycling in general and cycling to school among adolescents who lived within 4 km from their school by timing of cycle skills training participation**

| | Timing of previous cycle skills training | | | | |
|---|---|---|---|---|---|
| | **Yes, in primary school** (n=91) | **Yes, in intermediate school** (n=66) | **Yes, in both primary and intermediate school** (n=79) | **No cycle skills training** (n=319) | **p-value** |
| **Perceived behavioural control for cycling to school (continued)** | | | | | |
| **Environmental barriers** | | | | | |
| It is too far to cycle to school* | 2.0 ± 1.0 | 1.6 ± 0.8 | 1.6 ± 0.8 [d] | 2.0 ± 1.0 [c] | <.001 |
| There are no cycle lanes along the way* | 2.8 ± 1.1 | 2.7 ± 1.2 | 2.6 ± 1.1 | 2.7 ± 1.1 | .691 |
| The weather is too cold and wet to cycle to school* | 2.8 ± 1.0 [c] | 2.7 ± 1.0 [c] | 2.2 ± 1.0 [a,b,d] | 2.7 ± 1.0 [c] | <.001 |
| **Behavioural intentions for cycling to school** | | | | | |
| Behavioural intentions for cycling to school (I want/intend to regularly cycle to school (1=low to 7=high) | 1.9 ± 1.3 | 1.8 ± 1.4 | 2.0 ± 1.4 | 1.8 ± 1.4 | .838 |
| **Perceptions of the route to school** | (n=80) | (n=61) | (n=68) | (n=266) | |
| There are too many hills along the way* | 2.4 ± 1.1 [b,c] | 1.8 ± 1.1 [a,d] | 1.7 ± 1.0 [a,d] | 2.5 ± 1.1 [b,c] | <.001 |
| There is too much traffic along the route* | 2.4 ± 1.0 [c] | 1.9 ± 1.1 | 1.8 ± 1.0 [a,d] | 2.2 ± 1.1 [c] | .002 |
| There is one or more dangerous crossings along the route* | 2.3 ± 1.0 [c] | 1.9 ± 1.0 | 1.7 ± 0.9 [a,d] | 2.2 ± 1.1 [c] | <.001 |
| **Safety perceptions of cycling to school** | | | | | |
| It is unsafe to cycle to school* | 2.4 ± 1.1 [b,c] | 1.9 ± 0.9 [a] | 1.9 ± 0.9 [a,d] | 2.3 ± 1.0 [c] | <.001 |
| My parents think it is not safe to cycle to school* | 2.1 ± 1.0 [c] | 1.7 ± 0.9 [d] | 1.6 ± 0.9 [a,d] | 2.1 ± 1.0 [b,c] | <.001 |
| It is unsafe to cycle to school* | | | | | |
| **Attitudes towards cycle skills training** | 2.0 ± 1.0 | 2.1 ± 1.0 | 2.1 ± 1.0 | 2.2 ± 1.1 | .304 |
| Cycle skills training could make me safer in traffic* | 1.7 ± 0.9 | 1.7 ± 0.9 | 1.7 ± 0.9 | 1.7 ± 0.9 | .942 |
| I would take cycle skills training if it was available at my school* | 2.4 ± 1.1 [b,c] | 1.8 ± 1.1 [a,d] | 1.7 ± 1.0 [a,d] | 2.5 ± 1.1 [b,c] | <.001 |

[a] $p<0.05$ vs. yes, in primary school; [b] $p<0.05$ vs yes, in intermediate school; [c] $p<0.05$ vs. yes, in primary and intermediate school; [d] $p<0.05$ vs. no cycle skills training.

Data collected using a 7-point Likert scale (1=strongly agree to 7=strongly disagree, unless indicated otherwise)
*Data collected on a 4-point Likert scale (1=strongly disagree to 4=strongly.)