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Travel to school patterns and perceptions of walking to school in New Zealand adolescents before versus during the COVID-19 pandemic

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ABSTRACT

Background: In many countries, adolescents' active school travel rates were declining prior to the onset of the COVID-19 pandemic. Subsequent changes in active school travel have not yet been investigated systematically. This study compared school travel modes and adolescents' perceptions of walking to school 5–6 years before (period 1 (P1)) and 1–2 years after (period 2 (P2)) the onset of the COVID-19 pandemic.
Methods: Adolescents from Dunedin, New Zealand, completed an online questionnaire about their school travel and perceptions of walking to school in 2014–2015 (P1; n = 1463; 55.2% female)

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and 2021–2022 (P2; n = 1421; 44.4% female). Home-to-school distance was calculated using Geographic Information Systems. Data analysis included Chi-square tests, logistic regression and ordinary least squares regression.
Results: The odds of adolescents walking to school 'all the time' or 'most of the time' versus 'never', 'sometimes' or 'rarely' were significantly lower in P2 compared with P1. The odds following the pandemic onset were only 0.58 of those pre-pandemic (95% CI: 0.43–0.79), controlling for differences between the two samples. During the same period the proportion of adolescents living in households with ≥2 vehicles increased from 69% to 78%. Adolescents' attitudes towards walking to school indicated significantly lower intentions and higher perceived barriers to walking to school in P2 versus P1, although differences were smaller among those living within walking distance to school.
Conclusions: These findings highlight the need for renewed and extended efforts from cross-sectoral actors to support active school transport among adolescents during COVID-19 pandemic recovery efforts and in future similar events.

1. Introduction

A decline in rates of active transport to school among adolescents in many countries was reported in the years prior to the onset of the COVID-19 pandemic (Chillón et al., 2013; McDonald, 2007). In New Zealand, the proportion of adolescents' walking to school were largely unchanged between 1989/1990 (26%) and 2010–2014 (27%) (Ministry of Transport, 2015). During the same period the proportion of adolescents cycling to school decreased significantly (from 19% to 3%) while those being driven to school increased from 21% to 32% in 2010–2014 (Ministry of Transport, 2015). The low and declining levels of active transport to school in New Zealand children and youth were also reported in more recent years (Smith et al., 2019), with the most recent Physical Activity Report Card stating that 22% of adolescents in school years 7–10 (approximate age 12–15 years) use active modes of transport to school (Wilson et al., 2023). Given the documented health, academic, social, environmental and economic benefits of active transport to school (Gössling et al., 2019; Larouche et al., 2014; Waygood et al., 2017), addressing these concerning trends is important from a research, practice and policy perspective.

A number of factors contribute to the declining rates of active transport to school including increasing distance to school (McDonald, 2007), increasing vehicle ownership (Grize et al., 2010), decreasing availability of bicycles (Grize et al., 2010), sprawling neighbourhoods (Drivers of Urban Change, 2015; Stephenson et al., 2017), adolescents' preference for car-based transport (Hopkins et al., 2019) and, in some countries, educational policies that support choice of school beyond the closest school (Wilson et al., 2007).

Following the onset of the COVID-19 pandemic, travel demand declined dramatically due to lockdown-related mobility restrictions, closure of non-essential venues, cancellation of sporting and public events, and a wide-spread adoption of virtual activities, including working and studying from home (Beck and Hensher, 2020; Moore et al., 2020). Some of the changes in travel demand persisted after lockdown periods. For instance, an increased prevalence of hybrid working or working from home changed commuting patterns (MacLeod et al., 2022), and modal shifts continued including reduced public transport patronage and increased rates of private vehicle travel (Christidis et al., 2022; Nikolaidou et al., 2023). Most existing studies have focused on commuters and examined the impact of the COVID-19 pandemic on mode choice for travel to work (Harrington and Hadjiconstantinou, 2022; MacLeod et al., 2022; Plyushteva, 2022). Changes in adolescents' travel patterns since the emergence of COVID-19 have not yet been investigated systematically. One study reported that the COVID-19 pandemic did not significantly impact adolescents' travel mode choice for short trips (Liu et al., 2022). However, during the outbreak phase, adolescents reduced their frequency of outings and reported reduced willingness to use public transport (Liu et al., 2022).

Limited international evidence suggests adolescents' transport to school patterns changed following pandemic control lockdown periods. A study from Vietnam showed that, in 9- to 15-year-old children, prevalence of active transport to school decreased from 53% prior to the first COVID-19 lockdown in 2020 to 31% within two to four weeks of schools reopening after the lockdown (Nguyen et al., 2021). Rates of walking to school declined, rates of cycling and motorcycle travel increased, and rates of private vehicle travel and public bus use remained low with marginal changes (9% and 5% before the pandemic and 11% and 6% after the lockdown, respectively). The decline in active transport to school was greater in urban districts (compared with poorer, non-urban districts) and in the areas with the largest home-to-school distances (Nguyen et al., 2021). However, that study examined only the short-term effects of the COVID-19 pandemic within a few weeks of the first COVID-19 lockdown. The longer-term impact of the pandemic on adolescents' school travel patterns and their perceptions of walking to school (as the most common mode of active transport to school in high-income countries) remains largely unknown and requires further investigation to support preparedness efforts should new pandemics or similar disruptive events arise in the future.

New Zealand had a unique combination of stringent COVID-19 lockdowns and prolonged periods with few restrictions which may have impacted adolescents' school travel behaviors in different ways than in other countries. New Zealand's response to COVID-19 was rapid and amongst the most stringent internationally (Hale et al., 2021). Within three weeks of the first COVID-19 case reported in New Zealand on 28 February 2020, the country adopted a four-tier alert system, with levels 3 and 4 signaling 'lockdown'. In this alert system, schools opened at level 1 and 2 for all children, at level 3 only for children of essential workers and were closed at level 4. After the initial country-wide lockdown from 23 March to 13 May 2020, most of New Zealand (including Dunedin, the study city) remained at levels 1 or 2 for over a year, but moved into alert levels 3 and 4 from 31 August to 7 September 2021. (For a detailed overview of the

COVID-19 response in relation to New Zealand children and young people refer to Smith et al. (Smith et al., 2019). Given the unique context of New Zealand, and that limited information is available on COVID-19-related impacts on active travel for adolescents, more research is required on this topic.

This study compared modes of travel to school and perceptions of walking to school among New Zealand adolescents five to six years prior to (period 1 (P1)) and one to two years following the onset of (period 2 (P2)) the COVID-19 pandemic. Given that home-to-school distance is the strongest correlate of active transport to school (Babey et al., 2009; Ikeda et al., 2018; Larsen et al., 2009; McDonald, 2008) and is related to adolescents' and their parents' perceptions of enablers and barriers to walking to school (Mandic et al., 2022; Mandic et al., 2020), this research presents results both for the overall sample and for adolescents who lived withing walking distance to school.

2. Material and methods

2.1. Study background

This study was conducted in the city of Dunedin, a mid-size city (total population: ≈120,000), located on the lower South Island of New Zealand. Adolescents (age: 13–18 years; school years: 9 to 13) from all 12 secondary schools in Dunedin, New Zealand, participated in the Built Environment and Active Transport to School (BEATS) Research Programme: BEATS Study (Mandic et al.,

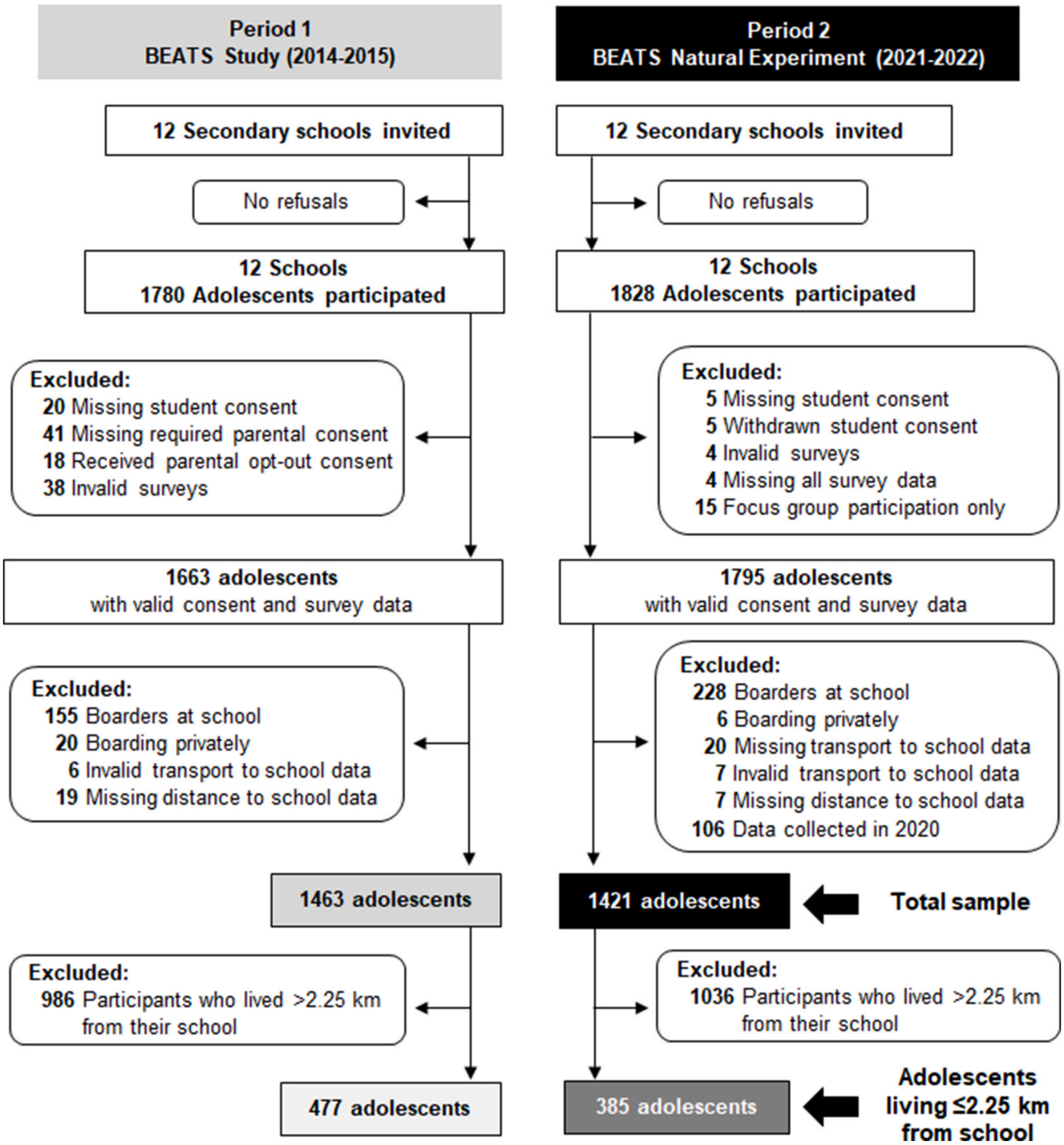

Fig. 1. Flow chart of participant recruitment and selection.

2015; Mandic et al., 2016) in 2014/2015 (P1; n = 1463) and BEATS Natural Experiment (Mandic et al., 2020) in 2021/2022 (P2; n = 1421).

P2 was originally designed to assess the effects of cycling and pedestrian infrastructure changes on adolescents' school travel patterns and perceptions of cycling and walking to school in the study city, Dunedin (Mandic et al., 2020). However, only a small portion of the original planned infrastructure changes were implemented during the study period. In addition, the onset of the COVID-19 pandemic in New Zealand coincided with the first two weeks of data collection for P2 in March 2020. Data collection resumed 14 months later (in May 2021) and was interrupted by the second COVID-19 lockdown in August 2021 and the Omicron outbreak in March 2022 before being completed in June 2022. All survey data collection for the BEATS Natural Experiment study (P2) occurred only during the periods when schools were open (alert levels 1 and 2). Since the infrastructure changes that we initially intended to investigate did not materialize to a sufficient extent during the study period, we used a pragmatic approach (Wolfenden et al., 2021) to leverage data collected as part of P1 and P2 and compare school travel patterns and perceptions of walking to school before and during the COVID-19 pandemic.

Study protocols for both studies have been published elsewhere (Mandic et al., 2020; Mandic et al., 2016). Both studies used the same research methodology. Adolescents were recruited through their schools. They received study information through their school and if interested, provided written consent prior to participation. For adolescents under 16 years of age, parental opt-in or opt-out

Table 1
Individual and household characteristics of the total sample and among adolescents who lived within walking distance to school (up to 2.25 km).

	Total sample		p-value^	Participants living within 2.25 km from school		p-value^
	Period 1 (2014–2015)	Period 2 (2021–2022)		Period 1 (2014–2015)	Period 2 (2021–2022)	
	n = 1463	n = 1421		n = 477	n = 385	
Number of schools	12	11		12	11	
Age (years) [n (%)]						
13	422 (28.9%)	436 (30.7%)		135 (28.4%)	108 (28.1%)	
14	335 (22.9%)	479 (33.7%)		101 (21.2%)	144 (37.4%)	
15	274 (18.8%)	250 (17.6%)		95 (20.0%)	65 (16.9%)	
16	219 (15.0%)	119 (8.4%)		76 (16.0%)	33 (8.6%)	
17	188 (12.9%)	114 (8.0%)		59 (12.4%)	31 (8.1%)	
18	23 (1.6%)	23 (1.6%)	<0.001	10 (2.1%)	4 (1.0%)	<0.001
Average (±SD)	15.1 ± 1.4	14.8 ± 1.3	<0.001	15.2 ± 1.4	14.9 ± 1.3	<0.001
Gender [n (%)]						
Males	656 (44.8%)	747 (52.6%)		207 (43.4%)	210 (54.5%)	
Females	807 (55.2%)	631 (44.4%)	<0.001	270 (56.6%)	169 (43.9%)	<0.001
Gender diverse[a]	N/A	43 (3.0%)		N/A	6 (1.6%)	
Ethnicity [n (%)]	(n = 1462)	(n = 1421)		(n = 477)	(n = 385)	
New Zealand European	1070 (73.2%)	939 (66.1%)		340 (71.3%)	239 (62.1%)	
Māori	160 (10.9%)	207 (14.6%)		55 (11.5%)	60 (15.6%)	
Pacific	59 (4.0%)	46 (3.2%)		17 (3.6%)	17 (4.4%)	
Asian	96 (6.6%)	56 (3.9%		37 (7.8%)	19 (4.9%)	
Other	72 (4.9%)	173 (12.2%)	<0.001	27 (5.7%)	50 (13.0%)	<0.001
Neighbourhood deprivation score [n (%)]	(n = 1437)	(n = 1419)		(n = 475)	(n = 385)	
1 (least deprived)	454 (31.6%)	414 (29.2%)		129 (27.2%)	82 (21.3%)	
2	356 (24.8%)	380 (26.8%)		97 (20.4%)	121 (31.4%)	
3	289 (20.1%)	235 (16.6%)		108 (22.7%)	62 (16.1%)	
4	212 (14.8%)	240 (16.9%)		92 (19.4%)	71 (18.4%)	
5 (most deprived)	126 (8.8%)	150 (10.6%)	0.018	49 (10.3%)	49 (12.7%)	<0.001
Number of vehicles at home (%)						
None	47 (3.2%)	19 (1.3%)		22 (4.6%)	6 (1.6%)	
One	402 (27.5%)	292 (20.5%)		173 (36.3%)	88 (22.9%)	
Two or more	1014 (69.3%)	1110 (78.1%)	<0.001	282 (59.1%)	291 (75.6%)	<0.001
Number of bicycles at home (%)						
None	349 (23.9%)	328 (23.1%)	0.750	131 (27.5%)	99 (25.7%)	0.790
One	299 (20.4%)	281 (19.8%)		104 (21.8%)	82 (21.3%)	
Two or more	815 (55.7%)	811 (57.1%)		242 (50.7%)	204 (53.0%)	
Distance to school (km)	3.7 (6.2%)	4.1 (6.8%)		1.3 (1.0%)	1.4 (0.9%)	
Median (IQR)	3.7 (6.2)	4.1 (6.8)	0.001	1.3 (1.0)	1.4 (0.9)	0.405
Walkable distance (≤2.25 km) (%)	477 (32.6%)	385 (27.1%)	0.005			N/A
Cyclable distance (>2.25–4.0 km) (%)	297 (20.3%)	309 (21.7%)				
Beyond cyclable distance (>4.0 km) (%)	689 (47.1%)	727 (51.2%)				

^p values are mainly for Chi square tests; the tests of differences in averages or medians are t tests for the difference in mean age and the Kruskal-Wallis test for the difference in medians.

[a] Gender diverse was an option in the questionnaire in Period 2 but not Period 1; the Chi square test excluded gender diverse.

consent was used in P1, based on each school's preference. Parental consent was not an ethics committee requirement for P2, but parents were informed of the study. The flow of participants into the study (with number of participants excluded at each stage) is presented in Fig. 1. Both studies received ethical approval from the University of Otago Ethics Committee (P1: 13/203; P2: 17/188) and P2 additionally received ethical approval from the Auckland University of Technology Ethics Committee (21/314).

2.2. Procedures

Adolescents completed a 35- to 40-minute online survey at their school under supervision of research staff. This analysis included survey items related to sociodemographic characteristics, travel to school, and attitudes, beliefs and intentions of walking to school.

For the purposes of this study, relevant demographic information included: date of birth, gender, ethnicity, number of vehicles and bicycles in the household, and home address. Adolescents were initially categorised into five ethnic groups ('Māori', 'Pacific', 'Asian', 'New Zealand European' and 'Other') using prioritized ethnicity for New Zealand (Ministry of Health, 2004). These groups were subsequently re-categorised into three ethnic groups for data analysis using logistic regression ['Māori', 'New Zealand European' and 'Other' (in a 3-category variable, 'Other' category included 'Pacific' and 'Asian')].

Participants reported frequency of use of different mode(s) of transport to school on a 5-point scale for each transport mode ('never', 'rarely', 'sometimes', 'most of the time', and 'all of the time'). Assessed travel modes included the following: 'by car (driven by others)', 'by car (driving myself)', 'by school bus', 'by public transport', 'on foot', 'by bike', 'by e-Bike', 'by e-Scooter (Lime scooter or other)', 'by bus and on foot', by car and on foot' and open text response for 'other modes or combinations'. Based on the dominant school transport mode(s) (i.e., modes used 'most of the time' or 'all of the time'), adolescents were categorised as users of 'motorised transport', 'active transport', or 'mixed active and motorised transport' (Mandic et al., 2017) as well as specific transport mode users: 'walkers', 'cyclists', 'other active mode(s)', 'car users (being driven or driving)', 'bus users (public and/or school bus)', 'other motorised mode(s)', 'bus users and walkers', 'car users and walkers', 'other mixed mode(s)' and 'no predominant transport mode users' (Mandic et al., 2023).

Survey items related to adolescents' perceptions of walking to school were informed by the theory of planned behavior (Ajzen, 1991) and complemented by additional items based on ecological models for active transport (Panter et al., 2008; Sallis et al., 2006), which were developed specifically for this study (for details refer to (Mandic et al., 2022); survey questions and composite scores are presented in Tables 2 and 3 below). Using either a 4-point Likert scale (ranging from 1 = strongly disagree to 4 = strongly agree) or a 7-point Likert scale (1 = strongly disagree to 7 = strongly agree), items assessed adolescents' attitudes, subjective norms, perceived behavioural control and intentions to walk to school as well as their perceptions of specific characteristics of the social and built

Table 2
Modes of transport to school among adolescents for entire sample and for those who lived within walking distance to school (up to 2.25 km).

	Total sample		p-value[a]	Participants living within 2.25 km from school		p-value[a]
	Period 1 (2014–2015)	Period 2 (2021–2022)		Period 1 (2014–2015)	Period 2 (2021–2022)	
	n = 1463	n = 1421		n = 477	n = 385	
Motorised, active or mixed modes [n (%)]						
Motorised transport	949 (67.2%)	799 (57.6%)		128 (27.6%)	122 (32.4%)	
Active transport	386 (27.3%)	252 (18.2%)		314 (67.8%)	206 (54.6%)	
Mixed modes	78 (5.5%)	337 (24.3%)	<0.001	21 (4.5%)	49 (13.0%)	<0.001
Usual transport modes to school (used 'most of the time' or 'all of the time' [n (%)]						
On foot	368 (25.2%)	226 (15.9%)		305 (63.9%)	192 (49.9%)	
By bicycle	11 (0.8%)	15 (1.1%)		4 (0.8%)	6 (1.6%)	
By bus and on foot	20 (1.4%)	138 (9.7%)		1 (0.2%)	1 (0.3%)	
By car and on foot	45 (3.1%)	162 (11.4%)		17 (3.6%)	46 (11.9%)	
By car (driven by others or driving)	702 (48.0%)	695 (48.9%)		120 (25.2%)	117 (30.4%)	
By bus (public or school bus)	202 (13.8%)	83 (5.8%)		6 (1.3%)	5 (1.3%)	
Other mode(s) or combinations	115 (7.9%)	102 (7.2%)	<0.001	24 (5.0%)	18 (4.7%)	<0.001
Frequency of walking to school [n (%)]						
All of the time	227 (15.5%)	145 (10.2%)		187 (39.2%)	118 (27.0%)	
Most of the time	211 (14.4%)	155 (10.9%)		138 (28.9%)	104 (27.0%)	
Sometimes	204 (13.9%)	160 (11.3%)		85 (17.8%)	66 (17.1%)	
Rarely	174 (11.9%)	179 (12.6%)		40 (8.4%)	51 (13.2%)	
Never	647 (44.2%)	782 (55.0%)	<0.001	27 (5.7%)	46 (11.9%)	<0.001
Estimated time to walk from home to school [n (%)]	(n = 1463)	(n = 1405)		(n = 477)	(n = 378)	
1–5 min	88 (6.0%)	60 (4.3%)		82 (17.2%)	51 (13.5%)	
6–10 min	128 (8.7%)	79 (5.6%)		117 (24.5%)	73 (19.3%)	
11–20 min	205 (14.0%)	170 (12.1%)		166 (34.8%)	142 (37.6%)	
21–30 min	202 (13.8%)	187 (13.3%)		90 (18.9%)	82 (21.7%)	
>30 min	687 (47.0%)	798 (56.8%)		18 (3.8%)	21 (5.6%)	
I don't know	153 (10.5%)	111 (7.9%)	<0.001	4 (0.8%)	9 (2.4%)	0.063

[a] Statistical tests were Chi square, apart from "usual transport modes" where Fisher's Exact Test was used (see text).

Table 3
Perceptions of walking to school – attitudes, beliefs, intentions, environmental and safety factors.

	Total sample					Participants living within 2.25 km from school				
	Period 1 (2014–2015)		Period 2 (2021–2022)		p-value^	Period 1 (2014–2015)		Period 2 (2021–2022)		p-value^
	(n = 1459)		(n = 1342)			(n = 474)		(n = 364)		
	(mean ± SD)	(% agree)	(mean ± SD)	(% agree)		(mean ± SD)	(% agree)	(mean ± SD)	(% agree)	
Attitudes										
Experiential beliefs for walking (walking is interesting/pleasant/stimulating) (1 = low to 7 = high)[b]	4.0 ± 1.6	N/A	4.0 ± 1.6	N/A	0.558	4.5 ± 1.4	N/A	4.4 ± 1.4	N/A	0.508
Instrumental beliefs for walking (walking is healthy/good/useful) (1 = low to 7 = high)[b]	5.0 ± 1.5	N/A	5.0 ± 1.4	N/A	0.217	5.4 ± 1.4	N/A	5.4 ± 1.3	N/A	0.694
Subjective norms										
Subjective norm for walking (parents/peers think I should walk) (1 = low to 7 = high)[b]	3.9 ± 2.0	N/A	3.4 ± 2.1	N/A	<0.001	5.5 ± 1.4	N/A	5.3 ± 1.6	N/A	0.129
Perceived behavioural control										
I have complete control over whether or not I walk to school (1 = no control to 7 = complete control)[b]	5.0 ± 2.0	N/A	4.8 ± 2.1	N/A	0.002	5.1 ± 1.9	N/A	5.1 ± 1.9	N/A	0.994
Behavioural intentions										
Behavioural intentions for walking (I want/intend to regularly walk) (1 = low to 7 = high)[b]	3.2 ± 2.2	N/A	2.8 ± 2.0	N/A	<0.001	5.0 ± 1.9	N/A	4.5 ± 2.1	N/A	0.001
Self-efficacy										
I am confident I could walk to school[b]	4.7 ± 2.4	N/A	4.5 ± 2.5	N/A	0.003	6.3 ± 1.3	N/A	6.2 ± 1.5	N/A	0.357
Personal barriers										
Personal barriers composite score for walking to school (1 = low to 4 = high)[a]	2.5 ± 0.8	N/A	2.5 ± 0.7	N/A	0.012	2.0 ± 0.7	N/A	2.1 ± 0.7	N/A	0.008
Convenience										
It is easier for someone to drive me to school, on the way to something else[a]	2.9 ± 1.2	67.5%	3.0 ± 1.2	69.9%	0.054	2.2 ± 1.2	41.4%	2.2 ± 1.2	43.1%	0.448
Environmental barriers										
It is too far to walk to school[a]	2.7 ± 1.3	55.5%	2.8 ± 1.3	60.7%	0.006	1.4 ± 0.8	10.8%	1.5 ± 0.8	12.6%	0.244
There are no footpaths along the way[a]	1.8 ± 1.1	25.4%	1.9 ± 1.1	30.0%	0.001	1.2 ± 0.6	5.9%	1.4 ± 0.8	11.3%	<0.001
The weather is too wet or cold to walk to school[a]	2.7 ± 1.0	64.2%	2.8 ± 0.9	66.1%	0.120	2.4 ± 0.9	51.9%	2.5 ± 1.0	52.5%	0.698
Perceptions of the route to school										
There is too much traffic along the route[a]	2.4 ± 1.1	49.0%	2.5 ± 1.1	54.9%	0.001	1.8 ± 1.0	27.8%	1.9 ± 1.0	30.4%	0.303
There is one or more dangerous crossings along the route[a]	2.3 ± 1.1	44.9%	2.5 ± 1.1	52.4%	<0.001	1.8 ± 1.0	27.0%	1.9 ± 1.0	30.7%	0.204
There are too many hills along the way[a]	2.3 ± 1.1	47.4%	2.6 ± 1.2	56.6%	<0.001	1.7 ± 1.0	24.3%	2.0 ± 1.1	32.9%	0.001
The route does not have good lighting along the way[a]	1.8 ± 0.9	21.3%	2.1 ± 1.0	32.1%	<0.001	1.4 ± 0.7	10.5%	1.5 ± 0.8	10.6%	0.132
Safety perceptions										
It is unsafe to walk to school[a]	2.0 ± 1.1	26.9%	2.0 ± 1.0	28.9%	0.033	1.4 ± 0.7	7.6%	1.4 ± 0.7	6.9%	0.219
My parents think it is not safe to walk to school[a]	1.9 ± 1.1	28.0%	2.0 ± 1.1	30.8%	0.009	1.3 ± 0.7	7.6%	1.4 ± 0.7	8.8%	0.068

^ p values are for tests of difference between Period 1 and Period 2.
[a] Data collected on a 4-point Likert scale (1 = strongly disagree to 4 = strongly agree).
[b] Data collected using a 7-point Likert scale (1 = strongly disagree to 7 = strongly agree).

environment including perceptions of safety of walking to school and route to school characteristics (traffic volume, crossings, hills and lighting) (Mandic et al., 2022).

Participants' home addresses were geocoded and used to calculate the New Zealand Index of Deprivation and home-to-school distance data. In P1, area level deprivation was calculated using the New Zealand Index of Deprivation for 2013 (NZDep2013) (Atkinson et al., 2014). In P2, the NZDep2018 was used (Atkinson et al., 2020; Salmond et al., 2006). The NZDep is an area-level measure of deprivation, calculated at the meshblock level (2013) or Statistical Area Unit (2018) level, using Census data. The

Table 4
Perceptions of walking to school (attitudes, beliefs, intentions, environmental and safety factors) among adolescents living within 2.25 km from school according to their use (most or all of the time) of active, motorised or mixed transport to school.

	Period 1 (2014–2015) Participants living within 2.25 km from school				Period 2 (2021–2022) Participants living within 2.25 km from school				p-value for time [a] transport mode interaction
	Active transport	Motorised transport	Mixed transport	p-value (between groups in Period 1)	Active transport	Motorised transport	Mixed transport	p-value (between groups in Period 2)	
	n = 311	n = 128	n = 21		n = 201	n = 119	n = 47		
Attitudes									
Experiential beliefs for walking (walking is interesting/pleasant/stimulating) (1 = low to 7 = high)[b]	4.7 ± 1.4	4.0 ± 1.4	3.9 ± 1.4	<0.001	4.7 ± 1.3	3.8 ± 1.4	4.6 ± 1.1	<0.0001	0.091
Instrumental beliefs for walking (walking is healthy/good/useful) (1 = low to 7 = high)[b]	5.6 ± 1.3	4.9 ± 1.4	5.3 ± 1.4	<0.001	5.6 ± 1.2	5.0 ± 1.3	5.5 ± 1.3	<0.0001	0.994
Subjective norms									
Subjective norm for walking (parents/peers think I should walk) (1 = low to 7 = high)[b]	5.9 ± 1.2	4.5 ± 1.3	5.3 ± 1.4	<0.001	6.0 ± 1.1	4.1 ± 1.6	5.1 ± 1.5	<0.0001	0.032
Perceived behavioural control									
I have complete control over whether or not I walk to school (1 = no control to 7 = complete control)[b]	5.0 ± 2.0	5.4 ± 1.6	4.7 ± 1.7	0.056	5.0 ± 2.0	5.3 ± 1.8	5.3 ± 2.0	0.2918	0.475
Behavioural intentions									
Behavioural intentions for walking (I want/intend to regularly walk) (1 = low to 7 = high)[b]	6.0 ± 1.3	2.7 ± 1.3	4.8 ± 1.6	<0.001	5.8 ± 1.3	2.6 ± 1.3	4.2 ± 2.1	<0.0001	0.576
Self-efficacy									
I am confident I could walk to school[b]	6.6 ± 1.0	5.7 ± 1.7	6.1 ± 1.6	<0.001	6.6 ± 1.0	5.8 ± 1.9	6.0 ± 1.8	<0.0001	0.838
Personal barriers									
Personal barriers composite score for walking to school (1 = low to 4 = high)[a]	1.7 ± 0.6	2.5 ± 0.7	2.3 ± 0.6	<0.001	1.8 ± 0.6	2.6 ± 0.6	2.2 ± 0.6	<0.0001	0.601
Convenience									
It is easier for someone to drive me to school, on the way to something else[a]	1.8 ± 1.0	3.0 ± 1.1	2.3 ± 1.1	<0.001	1.7 ± 0.9	3.2 ± 1.0	2.4 ± 1.2	<0.0001	0.177
Environmental barriers									
It is too far to walk to school[a]	1.2 ± 0.6	1.8 ± 0.9	1.7 ± 1.0	<0.001	1.3 ± 0.6	1.8 ± 1.0	1.6 ± 1.0	<0.0001	0.811
There are no footpaths along the way[a]	1.2 ± 0.6	1.3 ± 0.7	1.1 ± 0.5	0.244	1.3 ± 0.8	1.4 ± 0.9	1.7 ± 1.0	0.0406	0.082
The weather is too wet or cold to walk to school[a]	2.3 ± 0.9	2.8 ± 0.9	2.4 ± 0.9	<0.001	2.1 ± 0.9	2.9 ± 0.9	2.6 ± 1.0	<0.0001	0.238
Perceptions of the route to school									

(continued on next page)

Table 4 (*continued*)

	Period 1 (2014–2015) Participants living within 2.25 km from school				Period 2 (2021–2022) Participants living within 2.25 km from school				p-value for time [a] transport mode interaction
	Active transport	Motorised transport	Mixed transport	p-value (between groups in Period 1)	Active transport	Motorised transport	Mixed transport	p-value (between groups in Period 2)	
	n = 311	n = 128	n = 21		n = 201	n = 119	n = 47		
There is too much traffic along the route[a]	1.8 ± 1.0	2.0 ± 1.0	1.8 ± 1.1	0.160	1.8 ± 1.0	2.1 ± 1.1	1.8 ± 1.1	0.1812	0.922
There is one or more dangerous crossings along the route[a]	1.8 ± 1.0	1.9 ± 1.0	1.8 ± 1.0	0.702	1.9 ± 1.0	2.0 ± 1.1	1.7 ± 1.1	0.3349	0.834
There are too many hills along the way[a]	1.6 ± 0.9	2.0 ± 1.0	1.7 ± 1.2	<0.001	1.7 ± 1.0	2.4 ± 1.2	1.9 ± 1.0	<0.0001	0.274
The route does not have good lighting along the way[a]	1.4 ± 0.7	1.5 ± 0.8	1.4 ± 0.8	0.598	1.5 ± 0.7	1.6 ± 0.9	1.4 ± 0.6	0.0821	0.531
Safety perceptions									
It is unsafe to walk to school[a]	1.3 ± 0.6	1.5 ± 0.8	1.5 ± 0.9	0.009	1.4 ± 0.6	1.5 ± 0.7	1.5 ± 0.8	0.1733	0.727
My parents think it is not safe to walk to school[a]	1.2 ± 0.6	1.6 ± 0.9	1.6 ± 0.9	<0.001	1.3 ± 0.6	1.5 ± 0.8	1.5 ± 0.9	0.0137	0.340

[a] Data collected on a 4-point Likert scale (1 = strongly disagree to 4 = strongly agree).
[b] Data collected using a 7-point Likert scale (1 = strongly disagree to 7 = strongly agree).

Table 5
Adjusted odds ratios of walking to school ‘all the time’ or ‘most of the time’ versus ‘never’, ‘sometimes’ or ‘rarely’.

Effect	Odds ratio (95% CI)	p-value
Time period		
Period 2 vs Period 1	0.58 (0.43, 0.79)	0.001
Neighbourhood deprivation score (NZDep quintile)		
Quintile 1 (least deprived) vs Quintile 5 (most deprived)	0.79 (0.41, 1.51)	0.469
Quintile 2 vs Quintile 5 (most deprived)	0.91 (0.36, 2.28)	0.834
Quintile 3 vs Quintile 5 (most deprived)	0.86 (0.41, 1.82)	0.698
Quintile 4 vs Quintile 5 (most deprived)	0.75 (0.44, 1.25)	0.264
Age		
13 years vs 18 years	1.66 (0.91, 3.04)	0.101
14 years vs 18 years	1.57 (0.75, 3.26)	0.228
15 years vs 18 years	1.71 (0.64, 4.61)	0.288
16 years vs 18 years	1.23 (0.62, 2.45)	0.554
17 years vs 18 years	0.74 (0.31,1.80)	0.509
Gender		
Female vs male	0.91 (0.64, 1.30)	0.616
Ethnicity		
Māori vs New Zealand European	0.86 (0.64, 1.15)	0.304
Other vs New Zealand European	1.19 (0.76, 1.87)	0.442

Note: The odds associated with each characteristic were adjusted for the levels of the other characteristics, including time period, age, gender, ethnicity and the area level deprivation level (NZDep in quintiles).

NZDep index is categorised using deciles (1 = least deprived to 10 = most deprived), which were subsequently recategorised into quintiles for data analysis (quintile 1 = least deprived to quintile 5 = most deprived).

Home-to-school distance data were calculated using Geographic Information Systems (GIS)-based network analysis as described previously (Mandic et al., 2016). Distance along the shortest route from home to school was extracted using the walkable street network (not including standalone paths and tracks). Reasonable walking distance to school for adolescents ranges from 1.3 km to 3.0 km across various studies (Bere, van der Horst, Oenema, Prins and Brug, 2008; Chillón et al., 2015; Nelson, Foley, O’Gorman, Moyna and Woods, 2008; Pocock et al., 2019). A threshold of ≤2.25 km defined adolescents living within walkable distance to their school based on previous research conducted in the same city (Pocock et al., 2019).

In both P1 and P2, adolescents were also asked to estimate the time required to walk from their home to school. In P2, adolescents were also asked to report on their perceptions of a reasonable distance to walk and cycle to school and reasonable time for the school journey by different transport modes. Adolescents who did not respond to those questions or selected ’I don’t know’ response were excluded from those analyses.

2.3. Data analysis

The analysis was conducted using SAS STAT version 15.1. Data were analyzed in the entire sample as well as among adolescents who lived within walking distance to school, as these adolescents are the group who have the most realistic choice of active transport to school. The differences in proportions of adolescents in the specified categories between P1 and P2 were tested using Chi square tests, with one exception: as there were expected small cell counts for the disaggregation by specific combinations of travel modes to school ("usual transport modes"), which were too small (and too many) for the distributional assumptions of the Chi square, Fisher's Exact Test was used. Differences in means between the P1 and P2 were tested using t-tests. Differences in medians between the two time periods (for distance from home to school) were assessed using the Kruskal-Wallis test. To test whether there was evidence that the pattern of responses (attitudes, beliefs and intentions) according to transport mode changed between P1 and P2, ordinary least squares regression models were fitted with the attitude, belief or intention (measured on a scale) as the outcome and three explanatory variables: time, transport mode, and a time*transport mode interaction (Slinker and Glantz, 1988). The p-value shown in Table 4 is for a test that the coefficient for the last parameter (the interaction) is zero.

Finally, as the samples P1 and P2 differed in terms of some important demographic aspects, an adjusted model was fitted to the binary outcome of reported behavior walking to school 'all the time' or 'most of the time' versus 'never', 'sometimes' or 'rarely'. This estimated changes in the odds associated with the time period, controlling for age, gender, ethnicity and the area level deprivation level (NZDep in quintiles). To account for clustering of the observations at the school level, these clusters were specified in the model, using the SAS procedure SURVEYLOGISTIC (software SAS STAT version 15.1).

3. Results

Table 1 shows characteristics of all participants and those living within walking distance of their school. The P2 sample was younger than the P1 sample and had a higher proportion of males. The P2 sample had higher proportions of Māori and 'Other' ethnic groups, proportionally more living in socioeconomically deprived areas, higher proportions living in households with two or more vehicles, and higher proportions living further from school compared with the P1 sample.

Table 2 reports modes of transport to school among adolescents for the entire sample and for those who lived within walking distance to school (up to 2.25 km). Results show statistically significant differences between P1 and P2. Specifically, active transport to school rates were considerably lower at P2, for both the total sample and those living within walking distance of their school. Consistent with these results, frequency of walking to school was considerably lower at P2. For the whole sample, the proportion walking to school 'most of the time' or 'all of the time' was substantially lower during the COVID-19 pandemic (21%) compared to 5–6 years prior (30%). For adolescents within walking distance, the proportion of walking to school 'most of the time' or 'all of the time' was 68% at P1 but 54% at P2. In the total sample, the proportion of adolescents who estimated that it would take them more than 30 min to walk from home to school was 10 percentage points (pp) higher in P2 compared with P1 (Table 2).

In the total sample, half of adolescents (50.3%) perceived that home-to-school distance of up to 2 km is reasonable for walking to school. Fewer than half of adolescents (39.8%) considered that walking to school for up to 20 min was reasonable, whereas two-thirds (66.9%) perceived that a shorter school commute of up to 15 min was reasonable for walking to school. In this study, 10.8% of adolescents could not estimate reasonable time and 20.8% could not estimate reasonable duration for walking from home to school and were excluded from the respective data analyses.

Among adolescents who lived within walking distance to school, fewer than half (39.7%) considered home-to-school distance of up to 2 km to be reasonable for walking to school, whereas approximately two-thirds (63.5%) considered distance of up to 1.5 km to be reasonable for walking to school. In this subgroup, half of adolescents (53.3%) perceived school commute trips of up to 15 min to be reasonable for walking to school and only a quarter (24.5%) perceived walking to school of up to 20 min to be reasonable. In this group, a few adolescents could not estimate reasonable walking distance (3.7%) or duration (1.5%) and were excluded from the analyses.

Table 3 shows the adolescents' reported attitudes, beliefs and intentions of walking to school; responses to questionnaire items consisting of elements of the Theory of Planned Behavior; and environmental and safety factors. For the entire samples, there were consistent differences that indicate that on average the P2 adolescents had less favorable attitudes, beliefs, and perceptions of social, environmental and safety factors related to walking to school than the P1 sample. Consistent with the lower rates of active transport to school in P2 than P1 shown in Table 2, the measure of behavioural intentions for walking (*'I'*) was significantly lower for both the sample as a whole and for adolescents living within walking distance.

Table 4 shows average perceptions for the same set of attitudes and beliefs as Table 3 but constrained to adolescents who lived within walking distance to school. Results are shown according to the main transport mode reported for travelling to school and according to time period (P1 versus P2). The p-values are for t-tests with null hypotheses that the means are equal across the categories shown. The final column shows tests with a null hypothesis that the relationship between main transport mode and the given perception/attitude/belief did not change between P1 and P2.

Generally, attitudes and beliefs in favor of walking to school were more positive in adolescents who walked to school 'all the time' or 'most of the time'. The final column in Table 4 presents a test that the interaction between time period (P1 versus P2) and usual mode of transport to school is non-zero. This is an indication as to whether there is evidence that the pattern of responses changed between P1 and P2. Only one test was clearly statistically significant, for the subjective norm for walking ('*P*'), indicating that the subjective norm for walking was lower at P2 for those using predominantly mixed transport and, particularly, motorised transport, while it remained relatively stable for those using active transport to school.

Table 5 presents the results of a logistic model showing adjusted odds ratios of walking to school 'all the time' or 'most of the time' versus 'never', 'sometimes' or 'rarely'. As described above, the odds associated with each characteristic were adjusted for the levels of the other characteristics, including time period, age, gender, ethnicity and the area level deprivation level (NZDep in quintiles). The one statistically significant term in this adjusted model was for time period. This represented a reduction in the odds ratio associated with time period of 42% (estimated odds ratio 0.58 with 95% CI 0.43–0.79).

4. Discussion

4.1. Key findings

Key findings of this research are: first, the odds of adolescents walking to school 'all the time' or 'most of the time' versus 'never', 'sometimes' or 'rarely' were significantly lower in P2 compared with P1. The odds following the COVID-19 pandemic onset were only 0.58 of those pre-pandemic (95% CI: 0.43–0.79), controlling for differences between the two samples. Secondly, the proportion of adolescents living in households with two or more vehicles was 69% in P1 and even higher (78%) in P2. Thirdly, adolescents' attitudes towards walking to school also indicated significantly lower intentions and higher perceived barriers to walking to school during the pandemic compared with the pre-pandemic levels, although differences were smaller among those living within walking distance to school. Fourthly, subjective norms for walking were lower in P2 than in P1 for those using predominantly mixed transport and, particularly, motorised transport; they remained relatively stable for those using active transport to school.

In this study, rates of walking to school were lower during the pandemic compared with pre-pandemic levels both in the overall sample and among those who lived within walking distance to their school. These findings are consistent with the reported acute decline in active transport to school in 2020 in Vietnamese pupils mentioned above (Nguyen et al., 2021). The same study also reported a greater decline in active transport to school rates among 9- to 15-year-old Vietnamese who lived >1.5 km from their school versus those living within 1.5 km. One possible explanation for the observed decline in active transport in both studies could be related to parents working from home more often (a change in workplace setting related to the COVID-19 pandemic) and hence being more willing or available to drive adolescents to and from school. A higher proportion of households with two or more vehicles during the pandemic relative to the pre-pandemic study may have also contributed to greater reliance on private vehicles during school travel in P2.

Consistent with theoretical expectations derived from the Theory of Planned Behavior and previous active transport to school research using this framework (Mandic et al., 2022; Zaragoza et al., 2020), perceptions, attitudes and beliefs in favor of walking to school were on average stronger in adolescents who walk regularly to school. Furthermore, this pattern remained largely unchanged over time, with the exception of the subjective norm for walking ('*Parents/peers think I should walk to school*'), whose values were significantly lower in P2 than in P1. It is possible that a proportion of adolescents who might have walked to school in P1 were being driven to school in P2. Therefore, the parents driving their adolescents to school may be less in favor of the adolescent walking to school. Nguyen et al. (2021) reported that parents who had greater concerns about COVID-19 infections more frequently switched their child's mode of transport to school from active to motorised transport. In contrast, a study from China found that in parents of 6- to 19-year olds, parental perceptions of the COVID-19 risk had a significant impact on reducing rates of public transport and increasing private car travel to school but had no impact on rates of walking to school (Zhang et al., 2022). Inconsistent findings between those two studies could be at least in part explained by different school travel-related contexts. For example, the proportion of parents living within 1 km of their child's school was 13% in one of those studies (Nguyen et al., 2021) compared with 38% in the other (Zhang et al., 2022). Therefore, it is important to consider the context to make sense of differing patterns and perceptions about active transport reported in the literature during the pandemic across various geographical locations. For example, a qualitative study conducted with adolescents and parents from Israel reported a range of effects of COVID-19 on adolescents' active transport to various destinations (not limited to school) (Levi and Baron-Epel, 2022). Specifically, COVID-19 strengthened adolescents' and their parents' views of active transport as freedom; facilitated active transport with family and in the community; increased the personal use of active transport and for visiting friends; and placed emphasis on accessible and pleasing walking and cycling infrastructure (Levi and Baron-Epel, 2022).

In our study, adolescents' attitudes towards walking to school showed significantly lower intentions and higher perceived barriers to walking to school among the P2 sample during the pandemic compared with the pre-pandemic P1 sample. However, as expected given the key role of distance as determinant of active transport to school (Ikeda et al., 2018), the observed differences between P1 and P2 were lower among adolescents who lived within walking distance to their school. These findings are consistent with Nguyen and colleagues' study (Nguyen et al., 2021) which showed a greater decline in walking than cycling to school in Vietnamese children and adolescents due to perceptions that walking was more likely to lead to physical contact and COVID-19 virus transmission compared with cycling. There are important contextual differences between the study by Nguyen et al. (2021) and our study including differences in the proportion of households with two or more vehicles (8% versus 78%, respectively) and the timing of data collection (two to three weeks versus one to two years following the first COVID-19 lockdown within each country).

4.2. Implications

To the best of our knowledge, this is the first study to examine the longer-term differences in adolescents' transport to school patterns during the COVID-19 pandemic, while schools were open and low-level restrictions were in place, compared with pre-pandemic school travel patterns. The findings show a concerning low level of active transport to school among adolescents and less favorable perceptions of walking to school, even among adolescents who lived within walking distance to their school. Combined with higher levels of private vehicle ownership during the same period, these findings further emphasize the need for cross-sectoral efforts and multilevel interventions that target individuals, communities, built environment and policy to turn the tide from reliance on private vehicles for school travel to more active forms of transport (Mandic et al., 2020) to increase adolescents' physical activity levels and address climate change. The findings related to adolescents' perceptions of reasonable school travel distance and duration for walking to school have implications for urban design (10-, 15- and 20-min city), school locations, school travel planning, public transport and adolescents' physical activity.

4.3. Study strengths and limitations

Strengths of this study include a large representative sample of adolescents from the study city; a 100% school participation rate in both studies, although one school with data collection prior to the first COVID-19 lockdown was excluded from the P2 sample; the comprehensive conceptual framework used for assessment of adolescents' perceptions of walking to school; and supervised online survey data collection at schools during the pandemic period conducted only when schools were open.

Limitations include the comparison of data from two cross-sectional studies with different participants; pre-pandemic data collection five to six years before the onset of the COVID-19 pandemic; and the study survey not designed to assess person-level changes in travel to school patterns and perceptions of walking to school from immediately prior to versus during the pandemic. In addition, differences in neighbourhood level deprivation between the two samples need to be interpreted with caution due to different methods of calculation of the NZDep score in P1 and P2.

Although the BEATS Natural Experiment study (and therefore the questionnaire) was not designed in relation to the COVID-19 pandemic, taking a pragmatic approach and using the P2 data in this way has enabled a reasonable assessment of how travel patterns at a population level were impacted. The lower rate of walking to school during the pandemic was significant and remained so when differences in some of the socio-demographic characteristics of the P1 and P2 samples were controlled for in a logistic regression.

Additional research is needed to understand the wider context of 'why' adolescents experienced more barriers to walking to school during the pandemic compared with the pre-pandemic levels in some geographical contexts (such as New Zealand) but not in others. This would contribute to the necessary efforts to support active transport to school among adolescents during COVID-19 pandemic recovery efforts and in future pandemics or similar events.

5. Conclusion

During the pandemic period, participating adolescents reported lower levels of active transport to school (mostly walking), lower intentions to walk to school and higher barriers to walking to school compared with their peers pre-pandemic, although differences were smaller among those living within walking distance to school. These findings highlight the need for renewed and extended efforts from cross-sectoral actors to address barriers and encourage active school transport among adolescents, including practical policy responses to future pandemics or similar disruptive events. The findings also suggest the need for sustained investment in multilevel interventions that target individuals, communities, the built environment and policy to reduce reliance on private vehicles and increase rates of active forms of transport to school.

Data statement

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

CRediT authorship contribution statement

Sandra Mandic: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Supervision, Visualization, Writing – original draft, Writing – review & editing. **Enrique García Bengoechea:** Conceptualization, Formal analysis, Funding acquisition, Methodology, Writing – review & editing. **Kirsten J. Coppell:** Conceptualization, Funding acquisition, Methodology, Writing – review & editing. **Michael Keall:** Formal analysis, Funding acquisition, Methodology, Writing – review & editing. **Melody Smith:** Conceptualization, Funding acquisition, Methodology, Writing – review & editing. **Debbie Hopkins:** Conceptualization, Funding acquisition, Methodology, Writing – review & editing. **Susan Sandretto:** Funding acquisition, Methodology, Writing – review & editing. **Gordon Wilson:** Investigation, Methodology, Resources, Writing – review & editing. **Gavin Kidd:** Writing – review & editing, Investigation, Methodology, Resources. **Charlotte Flaherty:** Conceptualization, Investigation, Methodology, Project administration, Writing – review & editing. **Jennifer S. Mindell:** Writing – review & editing. **Janet Stephenson:** Writing – review & editing. **Kimberley King:** Investigation, Project administration, Writing – review & editing. **Kaisa Kentala:** Investigation, Project administration, Writing – review & editing. **Anna Rolleston:** Funding acquisition, Methodology, Writing – review & editing. **John C. Spence:** Conceptualization, Funding acquisition, Methodology, Writing – review & editing.

Declaration of competing interest

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

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