



BMJ Open Built environment changes and active transport to school among adolescents: BEATS Natural Experiment Study protocol

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ABSTRACT

Introduction Natural experiments are considered a priority for examining causal associations between the built environment (BE) and physical activity (PA) because the randomised controlled trial design is rarely feasible. Few natural experiments have examined the effects of walking and cycling infrastructure on PA and active transport in adults, and none have examined the effects of such changes on PA and active transport to school among adolescents. We conducted the Built Environment and Active Transport to School (BEATS) Study in Dunedin city, New Zealand, in 2014–2017. Since 2014, on-road and off-road cycling infrastructure construction has occurred in some Dunedin neighbourhoods, including the neighbourhoods of 6 out of 12 secondary schools. Pedestrian-related infrastructure changes began in 2018. As an extension of the BEATS Study, the BEATS Natural Experiment (BEATS-NE) (2019–2022) will examine the effects of BE changes on adolescents' active transport to school in Dunedin, New Zealand.

Methods and analysis The BEATS-NE Study will employ contemporary ecological models for active transport that account for individual, social, environmental and policy factors. The published BEATS Study methodology (surveys, accelerometers, mapping, Geographic Information Science analysis and focus groups) and novel methods (environmental scan of school neighbourhoods and participatory mapping) will be used. A core component continues to be the community-based participatory approach with the sustained involvement of key stakeholders to generate locally relevant data, and facilitate knowledge translation into evidence-based policy and planning.

Ethics and dissemination The BEATS-NE Study has been approved by the University of Otago Ethics Committee (reference: 17/188). The results will be disseminated through scientific publications and symposia, and reports and presentations to stakeholders.

Trial registration number ACTRN12619001335189.

INTRODUCTION

Low levels of physical activity (PA) and increased engagement in sedentary pastimes among adolescents are global public health

Strengths and limitations of this study

- This natural experiment follows a large comprehensive baseline survey involving all 12 secondary schools in Dunedin city, which recruited 1780 adolescents aged 13–18 years.
- The study methodology has been used previously in the baseline Built Environment and Active Transport to School (BEATS) Study, and includes objective measures of physical activity and the built environment.
- Environmental scans of school neighbourhoods and comprehensive mapping are novel methods.
- Limitations include self-reported travel to school data and objectively measured physical activity only in a subgroup of adolescents.
- In 2018, the newly elected coalition government of New Zealand signalled intentions to provide safe walking and cycling access to all schools; however, such built environment changes take time to plan and implement and are therefore unlikely to influence this study.

concerns.^{1,2} Although active transport to and/or from school (ATS) is a convenient way to reduce sitting time³ and to integrate PA into everyday life,^{4,5} rates of ATS among adolescents have been declining in many developed countries,⁶ including New Zealand (NZ).^{7,8}

NZ's transport system is dominated by high private vehicle ownership,⁹ near-complete reliance on fossil fuels,¹⁰ sprawling urban areas,^{11,12} educational policy with an emphasis on school choice,¹³ increasing numbers of adolescents being driven to school,⁷ low rates of walking and cycling to school,^{7,14,15} high rates of bicycle-related crashes in adolescents^{16,17} and other sociotechnical mobility cultures (eg, financial constraint). These factors reproduce car-dependent norms and practices^{18,19} and contribute to behaviours that inhibit active transport.



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In addition to individual, family, school and social factors, physical environment factors (including the built environment (BE)) are predictors of ATS.^{20–23} However, the impact of the environment on PA and sedentary behaviour is not consistent.^{24–25} This can be partly explained by an inadequate understanding of the local context. An ecological approach that examines the multiple levels of influence on ATS is essential for developing and identifying effective interventions to promote ATS. Since the randomised controlled trial (RCT) design is rarely feasible due to prohibitive costs associated with changes to the BE²⁶ and probable opposition presented by town councils and communities to RCTs affecting road infrastructure, natural experiments are considered a priority for examining causal associations between the BE and PA.^{27–28} Few natural experiments^{29–33} to date have examined the effects of walking and cycling infrastructure changes on PA and active transport in adults, and none have examined the effects of such changes on PA and ATS among adolescents. The practice-based evidence pathway to improving population health, exemplified in natural experiments, is an essential complement to the more established evidence-based practice pathway, typified in the RCT, and is often the only way to generate meaningful evidence to address critical questions about population health interventions.³⁴

The Built Environment and Active Transport to School (BEATS) Study, 2014–2017

The Built Environment and Active Transport to School (BEATS) Study was conducted in Dunedin city, NZ, in 2014–2017.^{35–36} It was an interdisciplinary collaboration with multisector partnerships involving the Dunedin Secondary Schools' Partnership, the local city council, the community and academia,³⁵ and was designed to provide evidence-based information about road safety issues around schools, inform the design of a cycle skills training programme and inform education policies. All 12 Dunedin secondary schools and 1780 adolescents participated.

Findings

The 2014–2015 BEATS Student Survey data showed that only 17.9% of adolescents met minimal PA guidelines,³⁷ and that rates of ATS in Dunedin may be context specific and at least in part attributed to BE-related factors.^{15–38–39} Specifically, school travel was dominated by motorised transport (60.1%),⁴⁰ the average distance to school was 6.2±7.4km⁴⁰ and less than half of adolescents attended their closest school.^{38–41} Dunedin adolescents had a preference for private car travel and a desire for and intention to learn to drive.⁴² Common barriers to ATS included long distance, personal factors (eg, heavy school bags), lack of social support, convenience of being driven to school, the weather, BE factors (intersection density and residential density), traffic safety concerns, cycling helmet legislation and school choice policies.^{14–15–38–39–41–43–46} Adolescents' perception of the safety of walking to school was the

strongest correlate of ATS.⁴⁷ The BE in school neighbourhoods correlated with adolescents' perceptions of the school route for walking and cycling.⁴⁷ Compared with walking, cycling to school was less common, perceived as less safe and received less social and infrastructure support.³⁹ A complex range of factors contributed to perceptions of cycling safety, including features and perceptions of the BE and traffic safety.⁴³

BEATS Natural Experiment: Study overview

Since 2014, on-road and off-road cycling infrastructure construction has occurred in some Dunedin neighbourhoods. Pedestrian-related infrastructure changes began in 2018. This has provided a unique and timely opportunity to conduct a natural experiment. The BEATS Natural Experiment (BEATS-NE) Study will measure the effects associated with BE changes (cycling and pedestrian infrastructure construction: the intervention) in Dunedin neighbourhoods on ATS and PA in adolescents attending a secondary school.

The objectives and hypotheses are:

Aim 1: To examine the associations between BE changes in Dunedin on transport choices and PA in adolescents enrolled in 'exposure' compared with 'control' schools.

Hypothesis 1: Compared with baseline (2014–2015), adolescents attending 'exposure' schools will have higher rates of ATS, particularly cycling, and greater overall PA levels than adolescents attending 'control' schools.

Aim 2: To examine the associations between BE changes in Dunedin on adolescents' perceptions of walking and cycling to school in 'exposure' compared with 'control' schools.

Hypothesis 2: Compared with baseline (2014–2015), fewer BE-related barriers and traffic-related safety concerns for ATS (particularly for cycling) will be reported by adolescents attending 'exposure' versus 'control' schools.

Aim 3: To identify factors associated with ATS in adolescents.

Hypothesis 3: Dedicated cycling infrastructure, BE characteristics of home and school neighbourhoods, dietary behaviours, school bag weight and anthropometric measures will be significantly associated with ATS among Dunedin adolescents.

METHODS AND ANALYSIS

Study setting

Dunedin is the seventh largest city by population (population: 130 000), yet second largest by territorial land area in NZ. The city's topography, transport infrastructure, climate and education setting offer the opportunity to examine the school travel practices of adolescents from both urban and more remote parts of the city (see figure 1).

Topography: Beyond the Central Business District, the city is surrounded by hills and ocean, and much residential housing are on the hillsides. This topography presents specific challenges for promoting active transport.

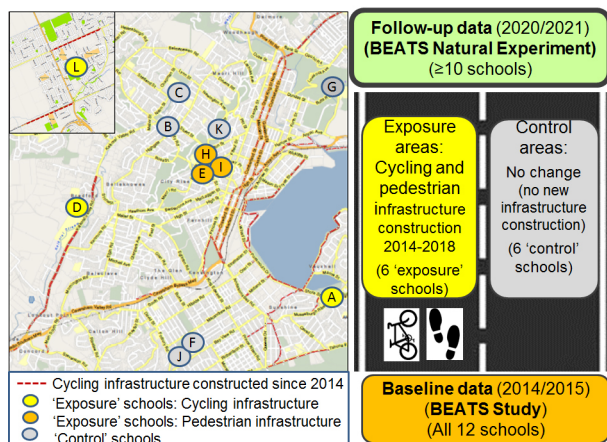


Figure 1 Built Environment and Active Transport to School (BEATS) Natural Experiment: intervention locations and study design.

Transport infrastructure: State Highway 1, a major highway running the length of NZ, passes through Dunedin on two one-way streets with a 50 km/hour speed limit through the Central Business District, and 60 km/hour beyond that area. These one-way streets also have some of the most developed cycling infrastructure in the city.

Climate: Dunedin's climate is generally temperate, with mild summers and cool winters (mean annual temperature: 11.0°C),⁴⁸ and unique microclimates arising from the highly varied topographical landscape.

Educational setting: Dunedin has 12 public secondary schools (5 coeducational, 3 boys-only and 4 girls-only schools); 8 regular and 4 special character (religious) schools, and less than half of adolescents enrol in the closest school.^{38 41}

Research design

In the context of a natural experiment, the BEATS-NE will be guided by ecological models for active transport^{21 49} that account for individual, social, environmental and policy factors (figure 2). The study will use the published BEATS Study methodology³⁶ with both quantitative and qualitative methods, which will be enhanced by novel research methods.

Intervention

The locations of BE cycling and pedestrian infrastructure changes since 2014 are presented in figure 1. The BE infrastructure changes have included both macroscale features (eg, building of new cycle lanes, creation of quiet streets) and microscale features (improvement in intersection design, pedestrian infrastructure, safety features, traffic calming measures, aesthetics). Specifically, infrastructure improvements included extended kerbs/footpaths and painted threshold markings at school zone gateways, platforms, variable electronic speed signs and advanced warning signs advising of approaching a school zone. Other improvements comprised new safe crossing points including extended kerbs and/or raised platforms,

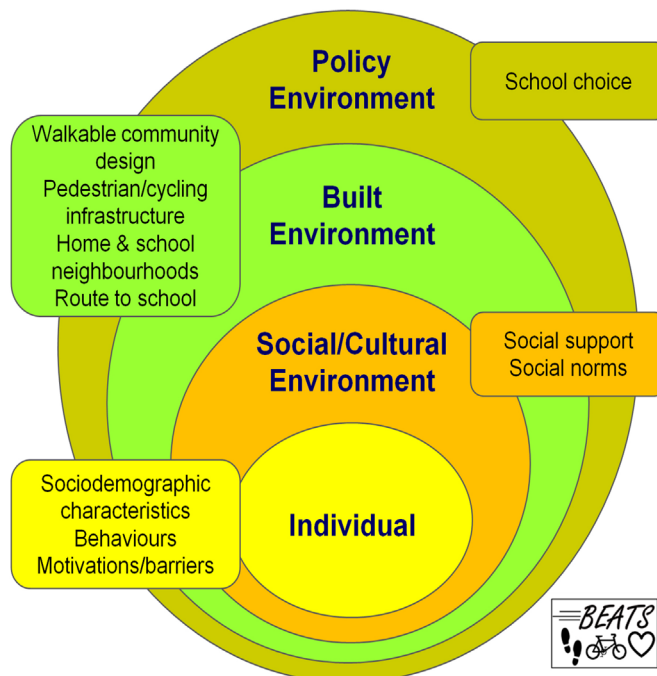


Figure 2 Built Environment and Active Transport to School (BEATS) Research Programme conceptual framework.

intersection design to slow down turning traffic manoeuvres and new drop kerbs to provide proper connections with tactile pavers to assist the visually impaired. The neighbourhoods of 6 out of 12 Dunedin secondary schools are affected (table 1, figure 1).

As this is a natural experiment, we have no control over circumstances that may arise during the study. In 2018, the newly elected coalition government of NZ signalled intentions to provide safe walking and cycling access to all schools.⁵⁰ While it is possible that these actions will influence our study, BE changes take time to plan and implement, so we do not expect the study to be compromised by these or other unanticipated events over the study period. We will nevertheless actively monitor and document any such changes and account for them in the analyses where possible.

Our study will measure associations between changes in ATS rates and attitudes in the exposure schools relative to changes in the control schools. As in any quasi-experimental study, the relevant exposures are those that are present in one arm of the study but not in the other. These exposures will be measured carefully as, for example, traffic calming introduced in one part of the city may or may not affect traffic speeds and consequent safety perceptions in another part of the city. We will maintain communication with the local road controlling authorities to identify what BE changes have been implemented with respect to the schools studied and the timing of our assessment of outcome measures for those schools.

Patient and public involvement

The BEATS and BEATS-NE Studies have been designed and implemented using a community-based participatory

Table 1 BEATS Natural Experiment: characteristics of exposure and control schools

	'Exposure' schools (n=6)	'Control' schools (n=6)
School type	4 co-ed; 1 boys-only; 1 girls-only	1 co-ed; 1 boys-only; 3 girls-only
School decile* (average (range))	7.5 (5–9)	8.0 (5–10)
School size—number of students (average (range))	658 (360–869)	514 (388–872)
Topography	3 on flat; 3 on hillside	3 on flat; 3 on hillside
Too many hills on the way to school† (average per school (range))	39% agree (6%–60%)	37% agree (17%–58%)
Active transport to school‡ (average per school (range))	24% (10%–45%)	21% (14%–31%)

Data presented as average (range) across schools.

*Deciles are a measure of the socio-economic position of a school's student community relative to other schools throughout the country' (decile 1='low' to decile 10='high').

†BEATS Student Survey 2014/2015 data (excluding adolescents residing >4 km from school and boarders at school).

‡Active transport to school only (excluding mixed modes and boarders at school); data from the BEATS Student Survey 2014/2015.

BEATS, Built Environment and Active Transport to School; co-ed, coeducational.

approach with the sustained involvement of key stakeholders: the Dunedin Secondary Schools' Partnership, Dunedin City Council, NZ Transport Agency and Māori and Pacific communities. They have been involved in setting research priorities, defining research questions and outcome measures, contributing to study design, study materials, research procedures and implementation, data analysis and preparation of research outputs, dissemination of results and the evolution of the BEATS Research Programme since inception.³⁵ For example, in response to the research priorities identified by community partners, the original BEATS Study also examined adolescents and their parents' perceptions of cycle skills training^{40 51} and the issue of school choice.^{38 41} The ongoing involvement of community partners is facilitating the generation of usable data and knowledge translation into evidence-based policy and planning. Findings to date have been adopted by end users, employed in the design of school/city-wide programmes and initiatives in Dunedin and have attracted interest of national organisations and Ministries of Health and Transport.

Recruitment of schools and adolescents

All 12 Dunedin secondary schools will be invited to participate. We anticipate at least 10, if not all, schools

will participate. Based on this, the eligible population will be ≈3750–4500 students (~25 students per class × ~3 classes participating per school year × 5 school years × 10–12 schools). For logistical reasons, the sampling of classes within schools will be left to the discretion of each school.³⁶ With an expected adolescents' participation rate of ~42% (based on the BEATS Study) from at least 10 schools, we will recruit 1600 adolescents aged 13–18 years. Recruitment procedures³⁶ will include: providing study information packages to all invited adolescents (and their parents) at their school 1–3 weeks prior to data collection; advertising the study in school newsletters; school principals sending a study invitation via email to adolescents and their parents; and providing study packages in prepaid envelopes for each school to send to parents without an email address. Adolescents will provide written consent prior to data collection. Based on discussions with the schools and the institutional ethics committee, parental consent will not be required as the study is considered low risk (ethics approval reference: 17/188). In a supervised classroom, consenting adolescents will complete (1) an online survey, (2) anthropometry measurements and school route map at school, with additional optional written consents for each of (3) PA assessment (n=420), (4) focus group participation (n=72), and (5) participatory mapping (n=200). We will survey an equal number of 'exposure' and 'control' schools in each school term to control for seasonal variations.

Assessment procedures

Assessment procedures³⁶ will include both quantitative and qualitative methods (table 2). The core data will include accelerometer-measured PA, anthropometry, Geographic Information System (GIS) BE measures and route to school drawn maps.

Student survey

Adolescents will be surveyed once using a 35–40 min BEATS Student Survey questionnaire³⁶ modified for this study (new aspects are highlighted in the following). The questionnaire will be delivered and completed online, during classroom time, with research assistants and a teacher present.³⁶ Questions will include demographics (age, gender, ethnicity, school, home address), family factors (family structure, bicycle/vehicle ownership), school choice,⁴¹ transport to school habits,³⁹ motivations for and barriers to ATS,³⁹ independent mobility (*new*),⁵² motorised transport, adolescents' perceptions of their route to school³⁹ and school neighbourhood environment (adapted Neighbourhood Environment Walkability Scale for Youth (test–retest reliability in adolescents: intraclass correlation coefficient (ICC) range 0.56–0.87))⁵³ and health behaviours³⁷ (PA, sedentary behaviour and dietary behaviour (fast food, confectionary and sugar-sweetened beverage intake⁵⁴)). Home address data will be used to calculate home-to-school distance and to determine NZ Indices of Multiple Deprivation⁵⁵ as a surrogate for students' socioeconomic status. School data will include

Table 2 BEATS Natural Experiment: assessments

	Baseline	Follow-up
Data collection (year)	2014/2015	2020/2021
Number of schools (out of 12)	12	≥10
Online student survey	1663	1500
Anthropometric measurements	1578	1400
School bag weight	1298	1200
Accelerometer assessment of physical activity	416	420
Basic mapping of route to school (safe/unsafe areas)	740	750
Comprehensive participatory mapping of school neighbourhoods and route(s)	N/A	200
GIS analysis (home and school neighbourhoods; route to school)	1488	1450
Environmental audits of school neighbourhoods (schools, n)	N/A	12
Focus groups (students, n)	54	72

BEATS, Built Environment and Active Transport to School; GIS, Geographic Information System; N/A, not applicable.

each school's decile and size. Deciles are a measure of the socioeconomic position of a school's student community relative to other schools throughout the country.⁵⁶

Anthropometry measurements

Although not a primary outcome, weight status is the key health indicator. It will be included in analyses of adolescents' lifestyle habits and access to food outlets. Height (Seca portable stadiometer), weight (A&D scale UC321, A&D Medical) and waist circumference (Lufkin measuring tape) will be measured twice using standard procedures³⁷ in a private, screened-off area in the classroom.³⁶ Adolescents will be asked to remove their shoes, jackets and sweaters prior to the measurements.³⁶ Body mass index will be calculated and weight status category will be determined using international age and gender-specific cut-points.⁵⁷ Adolescents' school bags will be weighed,⁴⁵ including a separate weighing of laptop computers/tablets, for students who bring them to school.

GIS analysis of the built environment

GIS analysis of the BE will be conducted for the home and school neighbourhoods and route to school. BE variables (network-based distance from home to school, land mix use, residential density, intersection density and topography indicators) and food outlet data will be derived through GIS analytical techniques using Esri ArcGIS V.10.6.1 software.³⁶ Distance from home to school will be calculated using both the shortest route on a topologically connected transport network,

based on geocoded home and school addresses and the actual route from home to school from paper maps.³⁶ Such GIS-calculated distances were similar to distances measured from Global Navigation Satellite System (GNSS) data collected on the home-to-school route.⁵⁸ GIS BE measures will include intersection density (the count of intersections within a buffer zone), residential density (the count of located address points within a specific buffer of each address) and the land use mix variable (calculated as the mean land use mix entropy⁵⁹ using Dunedin City Council reference data (values range from 0 (single class land use) to 1 (even distribution all land use classes))). The topography along the school route will be represented by the altitude difference and total altitude gain variables, calculated in conjunction with digital elevation data. GIS BE measures around home and schools will be assessed using 500 m and 1000 m network buffers and a 100 m buffer along school routes. Buffer sizes differ widely in previous GIS BE studies (400–1600 m around home/school and ≤200 m either side of any route).²³ Our choice of buffers follows the precedent of other NZ studies,^{60 61} derived from analysis of student track GNSS data, as well as other previous studies.^{44 62 63} Food outlets will be assessed around schools (500 m and 1000 m buffer) and along the common school routes (200 m buffer).⁶¹

Basic transport route mapping using annotated paper maps

All survey participants will trace their route from home to school on an A3 printed street map, annotating their transport mode and safe/unsafe zones.³⁶ The paper maps will be scanned, georeferenced and digitised into GIS compatible data. The digitised mapped route will be linked with the GIS BE measures. Map-measured routes have been used as valid in the past, significantly differing from GIS-based network measurements.⁶⁴ Therefore, this map-based collection method for all participants is added for robustness. From this data set, transport density and travel mode patterns will be examined. Safety categories determined from annotated BEATS maps in 2014/2015 (social, drivers and pedestrians, traffic, intersections/crossings, BE infrastructure and natural environment) will be used.⁶⁵ Spatial patterns of BE features and unsafe zones in the school neighbourhoods will be compared with 2014–2015 data^{65 66} and inform focus group discussions.

Comprehensive participatory mapping of the route to school and school neighbourhood

A subgroup of 200 adolescents (16–20 adolescents/school; half from 'exposure' schools) will be invited to participate in a separate comprehensive mapping session at their school (50–60 min), supervised by researchers. Participants will use paper maps (A3 size) to map their main route to school and identify their transport mode(s) as well as annotate safe/unsafe areas, as above. Alternative routes, road infrastructure, social, topographic and aesthetic factors and seasonal factors will also be drawn and annotated. In addition, participants will map their

school neighbourhood for facilitators of and barriers to walking and cycling to school. Maps will be processed as described above. For detailed annotations, a coding framework will be developed, implemented and visualised, informed by the 2018 BEATS Rural Study protocol and previous research.⁶⁷ Spatial patterns (densities, verified by spatial analysis) and adolescents' experiences and perceptions of BE features and unsafe zones en route and around schools will be described. Identified unsafe zones around schools will be discussed in focus groups.

Environmental audit of school neighbourhoods

School neighbourhoods were audited using the Microscale Audit of Pedestrian Streetscapes (MAPS) Global tool.⁶⁸ We adapted this tool for assessing school neighbourhoods, and collected data in 2017/2018 for all 12 Dunedin secondary schools using 500 m street network buffer around each school.⁴⁷ MAPS Global tool assesses microlevel BE features including street design, sidewalks and street crossings.⁶⁹ The tool assesses the features of the route (such as land use, destinations and street amenities), street segments (such as sidewalks, bicycle facilities and slope), crossings (such as crosswalk markings and crossing signals) and cul-de-sacs (such as size and amenities).⁶⁸ Items within each section are grouped into subscales and used to calculate the overall score.⁶⁹ MAPS items and subscales have predominantly moderate to excellent inter-rater reliability (ICC values of 0.41 and 0.60, respectively).⁶⁹ In children, adolescents, adults and older adults, 51.2% of all MAPS scores were significantly associated with walking/cycling for transport, 22.1% were associated with leisure/neighbourhood PA and 15.7% were associated with objectively measured PA.⁶⁸ After adjusting for walkability, the MAPS grand score was related to active transport with small-to-medium effect sizes ($d=0.44$ in children).⁶⁸ The overall score was related to objective PA in children.⁶⁸ The MAPS tool has been used to assess the route from participants' home to non-residential destinations.^{68–70}

Physical activity assessment

In a separate process, a subset of consenting adolescents will be provided an accelerometer (ActiGraph, GT3XPlus, Pensacola, FL, USA) 1–3 weeks after completing the survey.^{36 71} Research assistants will show adolescents how to attach, wear and use an accelerometer at school.^{36 71} They will be instructed to wear the accelerometer above the right hip for ≥ 12 hours/day for 7 consecutive days.⁷¹ The valid wear time criteria will be set as ≥ 5 days, for ≥ 10 hours/day.^{72 73} To encourage compliance, adolescents will be given a logbook to record the times and reasons for taking the device off during the day and they will be reminded to wear the accelerometer as instructed via email, phone calls or texts.⁷¹ They will also be asked to record their mode of transport to and from school and cycling activities daily for the 7 days (due to accelerometer underestimation of PA during cycling), and to return their accelerometer to their school. Activity counts will be stored in 15 s interval counts

to detect short bursts of vigorous PA.⁷⁴ Data will be analysed using MeterPlus software using Evenson cut-points.⁷⁵ Variables will include average time spent in light, moderate and vigorous PAs and being sedentary (daily, weekday and weekend) and throughout the schoolday (1 hour before school (08:00–09:00), during the schoolday (09:00–15:00), 1 hour after school (15:00–16:00) and late after-school hours (16:00–20:00)).⁷¹

Sample size

To power the study for Aim 1, 1500 students ('exposure'/'control' schools: 750/750) are needed. To account for 7% invalid consents/surveys based on the BEATS Study, we will recruit 1600 students ('exposure'/'control' schools: 800/800). Given the collected baseline data ($n=1663$), the resulting sample size of 1500 adolescents at the follow-up will be sufficient to detect a small difference in rates of any form of ATS (from baseline 40% to 46% or higher) in the 'exposure' schools relative to the 'control' schools with 80% power and type I error probability associated with the null hypothesis of 0.05.⁷⁶ This is based on a comparison of ATS rates for a sample size of 750 students in the exposure schools following BE changes compared with ATS rates among 2250 students in the control schools plus the exposure schools prior to the BE changes, using an uncorrected χ^2 test. We will also undertake a subanalysis to compare rates of ATS only versus combined motorised transport only and mixed modes. As all 12 Dunedin schools are likely to participate in the study, the schools are not clusters but are effectively strata with repeated measures across time, which will increase the power of the analysis to detect change beyond that required. Clustering at the classroom level within schools is likely to have a negligible effect on the required sample size. BEATS Student Survey data³⁶ analysed when calculating power and sample size requirements for this study showed no evidence that the variance within classes in schools was smaller than the pooled variance within the respective schools.

Statistical analysis

To examine the associations between ATS and the exposure (BE changes), we will use multilevel logistic models with a binary outcome (active travel or not) to estimate odds of walking and cycling compared with motorised transport to school. Explanatory factors will include the exposure (or for the controls, no exposure), distance to school and time period (baseline or post-exposure). Gender will be considered a moderator. Exposure effects will be determined from the coefficient of the interaction term between time period and exposure status. The regression models will also examine the effects of parental attitudes (as reported by adolescents), season, school neighbourhood topography (hillside/flat) and schools' decile on ATS rates. To address the various threats to the validity of a natural experiment, we are using a robust design with pre/post-measurements of both exposed and unexposed groups. At baseline (2014/2015), approximately 40% of adolescents used some form of ATS (alone or with motorised transport). Some

students will live in neighbourhoods with BE improvements but attend control schools. We will conduct sensitivity analyses excluding such students, and another analysis looking at the shortest route to school as an exposure at the student level (which may have benefited from BE improvements, or not). Using multilevel models (such as GLIMMIX in SAS, version 9.4), we will also examine differences in adolescents' perceptions and levels of PA as measured by the accelerometers for adolescents in the 'exposure' and 'control' schools. The latter analysis will also provide estimates of the contribution provided by ATS to overall PA for this group. We anticipate low levels of non-response, as has been achieved at baseline, in which case non-respondents will be excluded from the analysis. If for some reason non-response rates are higher than 25%, or we suspect that the response rates are systematically related to the response, we will conduct sensitivity analyses using propensity scores. In circumstances where non-response is non-negligible, we will use techniques such as multiple imputation in sensitivity analyses.

Focus groups

In the original BEATS Study, we employed qualitative findings to complement information derived from student surveys to obtain a more complete picture about adolescents' aspirations for car-based travel.⁴² In the BEATS-NE, the focus groups will provide a unique opportunity to explore school-specific survey and school neighbourhood mapping results with adolescents, allowing them to confirm and/or contest findings, as well as expand on them.⁷⁷ Depending on the nature of the research questions of specific sub-studies within the overarching BEATS-NE, we plan to take advantage of both quantitative and qualitative data and combine them using a pragmatic position which aims to 'tap the relative strengths and to make the most efficient use of both in attempting to understand social phenomena'.⁷⁸ This approach will be used to 'highlight discrepancies in data or interpretation' and to 'enhance the explanatory power' of our research.⁷⁹ Such an approach may entail using different strategies to combine or integrate quantitative and qualitative data according to the specific purposes of each sub-study in which mixed methods are used. For such research questions, focus group interviews will be guided using school-specific infographics with selected key survey findings. The investigators will take photos of school-specific unsafe zones identified in participatory mapping and use them as prompts in focus group discussions.

Interviews³⁶ will be conducted with age and gender-diverse groups of six adolescents per session (1 session per school × 8 schools). In addition, two sessions with Māori adolescents and two sessions with Pacific adolescents will be conducted as it is important in NZ to understand the cultural context for Māori who are the indigenous people and also for those of Pacific origin. The proposed size and number of focus groups is based on our previous and current work and should be sufficient to reach data saturation. However, if

needed, additional focus groups will be conducted to shed further light into specific issues being investigated until theoretical redundancy or saturation is achieved.

Appropriate tikanga (protocols) will be adhered to for Māori and Pacific focus group sessions and we will be guided by each school on tikanga. Focus groups with Māori and Pacific adolescents will be facilitated by a Māori health researcher (AR) and a Pacific community representative, respectively. Examining survey and mapping results with adolescents will tap into their in-depth understanding about the complexities of their mobilities, and will provide rich contextual information for interpretation of the quantitative data. Facilitators will record interviews digitally and take notes during the sessions. The digitally audio-recorded focus group data will be transcribed then checked for errors. The data will be read, coded and analysed thematically⁸⁰ by ≥2 investigators (CE, DH, SS) using HyperResearch and/or NVivo qualitative analysis software.

ETHICS AND DISSEMINATION

This study has been approved by the University of Otago Human Ethics Committee (reference: 17/188). The outcomes of the BEATS-NE Study are relevant to Māori and will support improving health and social well-being by providing relevant Māori-specific knowledge for health promoters and policymakers. Consultation with the Ngāi Tahu Research Consultation Committee (University of Otago) has been ongoing since 2013. This Committee provided guidance on ethnicity data collection and avenues for dissemination findings to Māori community, which have been incorporated into the BEATS-NE Study.

BEATS-NE findings will be shared with the academic community, key stakeholders and the wider community through established BEATS Research Programme dissemination channels, including peer-reviewed journal articles and conferences abstracts, academic, stakeholder and community presentations, technical reports and policy briefings, BEATS Research Programme website (www.otago.ac.nz/beats), Active Living Laboratory quarterly newsletter (www.otago.ac.nz/active-living) and media commentaries.³⁶

We will maximise the impact of the BEATS-NE Study locally, nationally and internationally. The study will generate relevant information for key stakeholders for planning future school-, neighbourhood- and city-wide BE changes to encourage ATS as a means of equitably increasing PA and decreasing sedentary behaviour among adolescents. The BEATS-NE will also provide timely, valuable and stakeholder-specific information for: (1) Dunedin City Council (the effects of the BE infrastructure changes on adolescents' transport to school habits and cycling behaviour); (2) Dunedin Secondary Schools' Partnership (changes in adolescents' perspective on school choice compared with 2014/2015); and (3) participating schools (comprehensive information about their students' transport to

school habits, perceptions of ATS and lifestyle habits to tailor future school-based health promotion initiatives).

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