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Abstract

Introduction: Built-environment interventions have the potential to provide population-wide effects and provide the means for a sustained effect on behavior change. Population-wide effects for adult physical activity have been shown with selected built environment attributes; however, the association between the built environment and adolescent health behaviors is less clear.

Aim: This New Zealand study is part of an international project across 10 countries (International Physical Activity and the Environment Network study – Adolescents) that aims to characterize the links between built environment and adolescent health outcomes.

Methods and Analyses: An observational, cross-sectional study of the associations between measures of the built environment with physical activity, sedentary behavior, body size, and social connectedness in 1,600 New Zealand adolescents aged 12-18 years will be conducted. Walkability and neighborhood destination accessibility indices will be objectively measured using Geographic Information Systems (GIS). Physical activity and sedentary behaviors will be objectively measured using accelerometers over seven consecutive days. Body mass index will be calculated as weight divided by squared height. Demographics, socioeconomic status, active commuting behaviors, and perceived neighborhood walkability will be assessed using the Neighborhood Environment Walkability Scale for Youth and psychosocial indicators. A web-based computer-assisted personal interview (CAPI) tool (VERITAS) and Global Positioning System (GPS) receivers will be used in a subsample of 300 participants. A qualitative research component will explore barriers and facilitators for physical activity in adolescents with respect to the built and social environment in a subsample of 80 participants.

Ethics and dissemination: The study received ethical approval from the Auckland University of Technology Ethics Committee (12/161). Data will be entered and stored into a secure (password protected) database. Only the named researchers will have access to the data. Data will be stored for 10 years and permanently destroyed thereafter. The results papers will be submitted for publication in peer-reviewed journals.

Strengths and limitations of this study

- Limited data exists on detailed and multilevel relationships of interaction between the social and physical environments specific to the NZ adolescents.
- The use of GPS/VERITAS will define the adolescents' geographical context and will provide accurate estimates of location in which physical activity takes place.
- The study forms the NZ arm of the international IPEN-Adolescents collaboration, whereby adolescents' physical activity and sedentary behaviour data are collected using a common methodology across multiple countries.
- Parents may self-select neighborhoods, therefore associations between built environment and walkability may in part be a reflection of neighborhood self-selection bias. Parents' neighborhood preference and self-selection will be accounted for in the analysis.
- When conducting spatial analyses on aggregated data, errors affecting the validity of results may be introduced. Geo-coded data and other techniques will assist in gaining a more accurate understanding of neighborhood boundaries for adolescents.

Built environment and physical activity in New Zealand adolescents: A cross sectional study

Introduction

The benefits of physical activity in youth are well documented [1-5]. Regular moderate-to-vigorous physical activity (MVPA) is positively associated with musculoskeletal health, cardiovascular wellbeing (e.g., healthy blood pressure, lipid and lipoprotein levels, cardiovascular autonomic tone), metabolic health, maintenance of a healthy weight, psychological wellbeing (e.g., improved self-concept, reduced anxiety and depression), and reduced risk of type 2 diabetes [6,7]. The accumulation of at least 60 minutes of MVPA per day is recommended for youth; however, accumulating physical activity below this threshold is still beneficial, especially for those whose health is at risk (e.g., overweight or obese youth) [6]. Despite awareness of the well-established benefits of physical activity, rapid changes in technology and the habitual environment over the last 50 years may have caused an increase in sitting, passive travel, and subsequently a reduction in incidental physical activity [8]. Furthermore, over the course of adolescence, physical activity typically decreases by 60-70% [9], while sedentary behaviour remains high at 7-14 hours per day [10-12]. The latter trend is particularly concerning given that emerging evidence suggests that sedentary behaviour has negative effects on health that are independent of the beneficial effects of physical activity [13-15]. Additionally, levels of activity during school age years significantly predict activity levels [16] and health outcomes [17] into adulthood.

Behavioural modification programmes have only achieved limited and mostly short term physical activity improvements [18-20]. For sustainable changes that optimise positive behaviours, it is important to understand that physical activity and sedentary behaviours occur within a broader ecological framework [21]. It is recognised that in order to be effective, complex integrated interventions are required that include supportive policies and social and physical environments [22,23]. Manipulating social and physical environments to be more health promoting will likely have sustainable and far-reaching impacts on population health behaviours and outcomes. We have previously examined the relationship of objective built environment measures (i.e., destination access, street connectivity, dwelling density, land use mix) with accelerometer-derived and self-reported physical activity in adults [24]. The work was part of a larger international study (IPEN-International Physical activity and Environment Network) with 12 participating countries. The potential of walkable neighborhoods for supporting health-enhancing increases in physical activity, at least for adults, was high [24]. A one standard deviation increase in neighborhood walkability variables yielded a 7-13% increase in physical activity. This effect is likely to be much higher than effects achieved through behavioural intervention alone [25,26].

While the evidence base for associations between the built environment and physical activity in adults has been steadily accumulating [24,27,28], our understanding of this relationship in adolescents is at its infancy [29-38], and at times non-intuitive [33,39]. Adolescents were consistently identified in our adult focus groups in our previous study as a sub-group whose changing needs for independent mobility and age- and culturally-appropriate forms of physical activity are less likely to be met, particularly in more suburban built environment forms [40]. In a recent review, land-use mix and residential density were the most highly correlated built environment variables with overall physical activity in youth [41]. However,

the review did not find any environmental variables that consistently correlated with physical activity in adolescents. Nonetheless, latest research indicates that adolescents' physically activity tends to occur close to their homes [42,43], and that strong associations exist between inactivity with lower neighborhood walkability, amount of public open space, and neighborhood safety [44], as well as higher densities of cul-de-sac networks [36]. MVPA is significantly lower for rural adolescents compared to those living in urban environments, however these differences between neighborhood type are not seen for BMI [45]. Geospatial data indicate that adolescent girls engage in higher intensity physical activity in places with parks, schools, and higher population density, and accumulate lower levels of physical activity in places with more roads and food outlets [32]. Low-income adolescents were physically active at fields/courts, indoor recreation facilities, small and large parks, and swimming pools [43] but reduced accessibility of physical activity facilities and food outlets was associated with being overweight [34].

In the Built Environment and Adolescent New Zealanders (BEANZ) study, we seek to understand the relationship of physical activity, sedentary behaviour, and body size with neighborhood-level built environment features in New Zealand (NZ) adolescents. We hypothesise that neighborhood walkability and neighborhood destination accessibility indices will be positively associated with minutes of MVPA, and inversely associated with minutes of sedentary time and body mass index (BMI). We will also investigate associations between the built environment and social connectedness to the community [46], the moderating effects of ethnicity and mediating effects of active commuting, neighborhood mobility, and perceived neighborhood walkability. A novel aspect of this study is the use of portable global positioning system (GPS) receivers together with web-based interactive mapping and geocoding software to examine adolescents' mobility and access to regular destinations. These ancillary data will enable the shape and scale of environmental exposure to be defined in considerable detail.

Our study forms part of the IPEN-Adolescent collaboration, using comparable data collection, management, and protocol sharing across 10 countries. By comparing diverse countries, built environmental heterogeneity can be captured (and therefore generate robust estimates of the real effects) while facilitating intra- and inter-country comparisons. The goal is to generate credible evidence to guide long-term town planning, policy change, and redesign of existing urban environments to maximise physical activity and community connectedness and minimise sedentary behaviour and body size, all key determinants of human health.

Method and analysis

The standardized checklist for the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) recommendations was used to ensure that all elements recommended were address within this section [47].

Design

BEANZ will be based on an observational, cross-sectional design that examines the associations of objective and subjective measures of the built environment with physical activity, sedentary behaviour, body size, and social connectedness in 1,600 NZ adolescents aged 12-18 years from eight secondary schools (approximately 200 participants per school). Demographics, socioeconomic status, active commuting, psychosocial indicators, and perceptions of the built environment will be measured in the full sample. A GPS and interactive mapping sub-study of approximately 300 participants will assess neighborhood mobility by geolocating participants' destinations, modes of travel, activity locations, walking/cycling area, and perceived neighborhood boundaries. Focus groups will explore barriers and facilitators for physical activity with respect to neighborhood built and social environment in a subsample of approximately 80 participants. Data will be collected from two major cities in New Zealand: Auckland and Wellington. Auckland is the largest city in New Zealand with a population of approximately 1.4 million residents (one third of the country's population) [48], with a population density comparable to Los Angeles and Helsinki [49]. Wellington, the capital city of New Zealand, is located on the southern part of the North Island and has a population density comparable to Vancouver and Honolulu [49]. Ethical approval was received by the Institution's Ethics Committee (AUTEC, 12/161).

Neighborhood, school and participant selection

Associations between exposure and outcome variables are estimated based on data collected using a multistage sampling strategy. This strategy maximises heterogeneity in the exposure variables (built environment) while allowing comparisons to be made between those of low and high socioeconomic status (SES). In the first instance, GIS will be used to calculate three built environment measures – street connectivity, residential density, and land use mix –for each meshblock (smallest census tract units available in New Zealand) [40]. The raw scores for these built environment measures will be normalised and summed to create a basic walkability index. Next the basic walkability index and and pre-existing deprivation data (NZ Dep 2006) will be used to classify all Auckland and Wellington urban meshblocks) into one of four strata: (1) higher walkable, higher SES; (2) higher walkable, lower SES; (3) lower walkable, higher SES; and (4) lower walkable, lower SES. Meshblocks with the top four walkability/SES deciles are classified as higher walkable/SES, and meshblocks with the bottom four walkability/SES deciles are classified as lower walkable/SES. Meshblocks with walkability or SES in deciles 5 and 6 are excluded.

School selection will be based on convenience and close proximity to large numbers of meshblocks in each of the four strata. Within each school, all potential participants will be sampled, regardless of the quadrant they reside, and for each participant walkability will be calculated: all students will be assigned to the strata of the meshblock they primarily reside in. This procedure will take place prior to the consent process. Adolescents living in one of the four meshblock strata will be invited to participate in the study. Participation in the study will require written, informed consent from a parent or caregiver and written assent from the adolescent. Subsequent schools will be selected on the basis of the quadrants that need to be balanced. In addition to this approach, care will be taken to balance student numbers across the four strata both within and across schools. A similar sampling strategy was used in our previous study of the environmental correlates of physical activity in adults; the heterogeneity generated by this technique permitted several meaningful associations to be detected [40]. A sub-sample of approximately 40 participants will be randomly selected from each school for the GPS and interactive mapping measurements.

Sample size

In adjusted multilevel models, it has been estimated that a sample of 1,600 adolescents recruited from two schools within each stratum (eight in total) would allow the detection of a small effect size (i.e., 1.4% of explained outcome variance found in similar studies conducted elsewhere [50]) with 80% power. The calculated sample size assumes a two-tailed probability level of 5%, a conservative clustering effect equivalent to an intra-class correlation coefficient of 0.10, and a regression model with 25 background covariates explaining 25% of the outcome variance (comparable to what might be expected from the selected variables). With an anticipated sample size of 320 Māori adolescents (our smallest sub-group comparison), the corresponding detectable effect size will be 7% of explained outcome variance (medium effect size).

Exposure, outcomes and covariates

Exposures

GIS data provide multiple spatially-referenced layers that can be used to create meaningful and objective exposure measures of the built environment. They are used to objectively characterise the built environment surrounding the primary home address of each participant and can be applied across a range of road network buffers (e.g., 500 m, 800 m, 1000 m, and 1600 m) in order to evaluate differences between various limits of exposure. Road network buffers can be created to define areas that can be reached on the street network system, but exclude areas that are not accessible due to major barriers (motorway, river, lake). Two main indices, each a composite function of 2-8 other variables, are used to assess physical environmental features: walkability index [51] and neighborhood destination accessibility index [52]. These are described in more detail below. All exposure measures (Table 1) follow the common protocols established for the international IPEN-Adolescents collaboration.

Table 1. Summary of study exposure, outcomes, and covariate

Exposure	**Covariates**
Detailed walkability index	Demographics
- Net residential density	- Age
- Land use mix	- Sex
- Retail density	- Ethnicity
- Street connectivity	- School
- Street discontinuity	Socioeconomic status
Neighborhood destination accessibility index	- Parent education
- Education destinations	- Parent occupation
- Transport destinations	- Family car ownership
- Recreation destinations	- Household crowding
- Social and cultural destinations	Active commuting
- Food retail destinations	- Frequency of active commuting
- Financial destinations	- Duration of active commuting
- Health destinations	Neighborhood mobility
- Other retail	- Frequency and location of regular destinations
Outcomes	- Frequency and location of activity
Physical activity behaviour	- Total walking area
- Minutes of MVPA	- Total cycling area
- Minutes of light activity	- Perceived neighborhood boundary
Sedentary behaviour	Perceived neighborhood walkability
- Minutes of overall sedentary activity	- Perceived residential density
- Minutes of television watching	- Perceived land use mix
Body size	- Perceived traffic/crime safety

- Body mass index - Waist circumference	- Perceived aesthetics Psychosocial indicators - Self-efficacy - Cons/barriers - Family support - Peer support Weather - Total rainfall - Mean temperature - Hours of daylight

Detailed walkability

The detailed walkability index is a summary score of five distinct variables calculated within GIS: net residential density, land use mix, retail density, street connectivity, and street discontinuity. This protocol was created for the US-based Neighborhood Quality of Life Study project, [51] and has been subsequently implemented in the US-based TEAN study [53], the Australian PLACE study, [54] and all IPEN Adult country study sites [55].

Neighborhood Destination Accessibility

Pedestrian access to destinations will be calculated using the Neighborhood Destination Accessibility Index (NDAI) [52]. The NDAI is an objective measure of pedestrian access to neighborhood destinations; it characterises the distribution of urban infrastructure within an 800m street network distance from residence. The NDAI has an advantage over most previous area-level measures of the urban environment in that it captures the range and intensity of everyday destinations such as schools, supermarkets and cafes, which may encourage active travel and enhance recreational physical activity at the population level. As well, the NDAI has been specifically designed for the New Zealand environment. The eight domains captured in the NDAI are education, transport, recreation and play, social and cultural, food retail, financial, health, and other retail.

Outcomes

Physical Activity

Minutes of MVPA will be objectively measured using hip-mounted triaxial accelerometers (Actigraph GT3X+) over seven consecutive days. The GT3X+ is a small, durable, and water resistant device worn on an elastic belt that records the frequency, duration, and intensity of physical activity with a high level of accuracy and precision [56]. Participants are asked to wear the Actigraph during all waking hours (except when bathing or swimming) for seven days; however, at least five complete days (including at least one weekend day) will be required for analysis to ensure reliable estimates of MVPA [57]. Consistent with previous research, a valid day will be defined as at least 10 hours of data for weekdays and 8 hours for weekend days; non-wear time will be defined as 60 minutes of consecutive zero counts [58,59]. In addition, each participant will be given a seven-day compliance log to complete daily, which assists with identifying non-wear periods. Upon collection of the accelerometer, data are downloaded and screened for completeness and possible malfunction using the Meterplus software (www.meterplussoftware.com). Accelerometer count data will be classified into minutes of light, moderate, and vigorous activity using thresholds developed by Evenson and colleagues [60]; these have performed well in a recent comparison of accelerometer count thresholds for youth [61].

Sedentary Behaviour

Minutes of sedentary activity will be objectively assessed using the GT3X+ accelerometer over the seven-day measurement period. The aforementioned cut-points established by Evenson and colleagues [60] will be used to define sedentary time (< 100 counts per minute).

Body Size

Height, weight, and waist circumference of each participant will be measured by trained field researchers using a stadiometer, calibrated scales, and a tape measure. These procedures occur immediately before the researchers distribute the accelerometers; participants wear light clothing and shoes are removed. BMI will be calculated as weight divided by squared height. Participants are classified into weight status categories using age- and sex-specific BMI thresholds [62].

Covariates

Demographics and socioeconomic status

Age, sex, ethnicity, and SES will be collected from the participants. Consistent with the IPEN-adolescents protocol, household income will be the preferred SES indicator, but highest level of parental education will be used when income is unavailable.

Active commuting

The frequency, distance, duration, and mode of all active commuting trips to or from the home address in the previous six months will be assessed with the CAPI. The recall of each trip will be aided by a basic travel log (time, location, and mode of transport only) to be completed nightly with the accelerometer compliance log. Participants will be asked to bring this information with them to the subsequent CAPI.

Neighborhood Mobility

The majority of studies investigating the built environment and health have focused exclusively on residential neighborhoods as a predictor of exposure [63,64], and overlooked the prospect that a large proportion of activity choices may be influenced by additional environments that are experienced during daily routines. This may reduce the accuracy of environmental exposure assessment [65] and introduce errors that may confound research results. It has been suggested that investigating aspects of daily mobility (regular destinations and the movement between them) will be important to enhance the assessment of exposure [66] and resolve the Uncertain Geographic Context Problem [67]. Using GPS and interactive activity destination questionnaires, we aim to accurately capture the full extent of daily mobility, and its mediating built environment effect on health.

The Visualization and Evaluation of Route Itineraries, Travel Destinations, and Activity Spaces (VERITAS) is a web-based CAPI tool integrating interactive mapping capacities (based on Google Maps) and has the potential to explore destinations both inside and outside the residential neighborhood. VERITAS was initially developed and tested for the RECORD Cohort Study, a major longitudinal study of over 7,200 French adults [68-71]. While we will be using GIS to provide an objective assessment of the surrounding environment (i.e., exposure measures), VERITAS will allow the research team to search and geolocate participants' regular destinations (visited within the previous 6 months), activity locations, walking/cycling area, routes and modes of travel between locations, travel companions, and perceived or experienced neighborhood boundaries (i.e., neighborhood mobility). The VERITAS programme will run through an internet browser on a laptop computer, and will be designed to automatically upload all participant responses to our secure database when connected to a wireless network. Spatio-temporal data will be collected using the Qstarz BT-Q1000XT GPS receiver (Qstarz International, Taipai, Taiwan) which has been deemed one of the more accurate portable GPS receivers on the market [72]. The GPS will be worn in a pouch alongside the accelerometer. GPS data will be cleaned, filtered and merged with accelerometer data using the Personal Activity Location Measurement System (PALMS, refer to: https://ucsd-palms-project.wikispaces.com) [73]. The merged data streams retrieved from PALMS will be disaggregated into discrete trips and imported into ArcGIS for further analysis. Data obtained from GPS and VERITAS differ both temporally (previous 1 week and 6 months, respectively) and spatially (a continuous sequential polyline compared with point data). Although VERITAS will be able to obtain data for extended periods, it lacks the temporal sequence of events available from GPS tracking. However, as short periods of GPS monitoring may not truly represent destinations visited over extended periods, the combination of both has been recommended to create complementary and more robust measures of environmental exposure [70].

The neighborhood mobility data will allow the demarcation of the territorial range by active travel modes. A spatial 'polygon' will be created consisting of a multisided geometric shape surrounding the home address that connects the various locations to which participants claim to have walked or cycled. The area (m^2) within these polygons will be calculated and used to define separate shapes based on the travel modes. In situations where participants walk or cycle to only one location (e.g., school) the polygon area will be the distance between the location and home addresses multiplied by 1 m. As with the active commuting assessment, the recall of visited locations and trips will be aided by the travel log that will be completed daily. Finally, using VERITAS, each participant will be able to map their perceived neighborhood boundary, allowing us to isolate the effects of their self-defined neighborhood environment on the outcome measures.

Perceived Neighborhood Walkability

In order to understand the mediating effect of individual perceptions of the neighborhood on the relationship between the objectively-measured built environment and physical activity behaviour, the Neighborhood Environment Walkability Scale for Youth (NEWS-Y) [81] will be administered as a self-completion hard copy survey. NEWS-Y is based on the NEWS, which has demonstrated good reliability and validity [74-78]. In addition to the GIS-based walkability index variables (residential density, land use mix, street connectivity), NEWS-Y assesses pedestrian/cycle facilities, aesthetics, traffic safety, and crime safety. The ten NEWS-Y subscales have acceptable test-retest reliability (ICC: 0.56-0.87) and specific subscales were correlated significantly with physical activity for adolescents [79].

Psychosocial Indicators

A small number of psychosocial variables associated with adolescent physical activity will be measured in the study. These include: self-efficacy; perceived barriers to being physically activity; family support; and peer support [79]. These variables have shown the most consistent psychosocial correlations with adolescent physical activity in the literature [80].

Further, by including such items we are able to examine our findings within a multilevel framework thereby accounting for and separating the various layers of influence (i.e., individual, social, and physical environments) [81].

Weather

We have previously demonstrated the significant impact of inclement weather conditions on physical activity in New Zealand children [82]. To monitor these potential confounding effects we will obtain hourly rainfall, mean temperature, and hours of daylight statistics from the New Zealand Met Service for each data collection day and use these as covariates in the models.

Procedures

Data will be collected from participants within the school setting in school hours. During the measurement session, the NEWS-Y [79] questionnaire will be administered, anthropometric measures will be taken and accelerometers and compliance logs will be distributed. Text messages will be sent to adolescents/parents before data collection session as a reminder to attend. A random sub-sample of 40 adolescents per school will be allocated a GPS receiver to wear in conjunction with the accelerometer, and will complete the VERITAS interview. All participants will be instructed on the correct use, wear-time, and care of the equipment. Participants will be issued with a $20 shopping voucher upon completion of data collection and return of the monitors and compliance logs.

Quantitative Analyses

The proposed dataset will have a hierarchical independent variable structure which consists of person-level observations nested within neighborhoods and schools. The main aim of the study is to examine confounder-adjusted associations of environmental variables with physical activity and body size outcomes. For this purpose, cross-classified (by neighborhoods and schools) generalized linear mixed models (MGLM) with random intercepts will be used. These can account for multiple sources of dependency (schools and neighborhoods) and different types of data (e.g., continuous or binary) following a Normal or other types of distributions (e.g., negative binomial, Poisson) [83]. MGLMs perform well when the number of observations across areas is highly unbalanced, [84] which will be relevant to this project as the number of participants may vary substantially across schools and neighborhoods. Given the relatively small number of strata included in the study, MGLMs will be estimated using Restricted Maximum Likelihood (REML) or Bayesian Markov chain Monte Carlo (MCMC) methods with non-informative priors, [85] the latter appropriate for binary (e.g., overweight/obese vs. normal weight) [85,86] or non-normally distributed outcomes [83]. Non-linear relationship will be examined using restricted cubic splines [87]. A probability level of 0.05 will be adopted.

Qualitative Methodology

A total of 16 focus groups, with approximately 5-8 participants, will be conducted at eight participating schools. Variability in walkability will be sought by recruiting two schools in Auckland (representing relatively low walkability) and Wellington (relatively high walkability). However students within focus groups will be selected to represent a range of neighborhood settings to facilitate discussion on differing experiences of the built environment. Participants will also take part in the quantitative component and completed all data collection. To aid open discussion and allow meaningful comparisons separate focus groups will be conducted by age, with younger students (approximately 12-14 years) further stratified by sex, and older students (approximately 15-18 years) in mixed sex groups [43]. Focus groups will be conducted using 40 min school periods to accommodate school timetables semi-structured interview. The focus groups are designed to examine the enablers and barriers to being physically active, particularly with regard to active transport, engagement in formal and informal physical activity, safety, and social drivers. Researchers will specifically seek discussion on activity within participants' residential neighborhood and school environments as well as alternative activity spaces in their everyday lives, including those outside of their geographical suburbs. Maps of local environments to prompt discussion on where youth are active (and where they avoid), types of activity, and travel routes will be used. Interviews will be digitally recorded and transcribed by group, with all individual identifying information removed.

Qualitative Analyses

Following transcription a coding framework will be developed using NVivo software to organise data generated by the project research questions (deductive) and emergent topics (inductive) [88]. Using data extracted from codes, thematic analyses will be conducted to examine issues with regard to the built environment and physical activity. Analyses will be conducted across and within groups to examine commonalities and differences by built environment settings and individual factors (i.e., sex, age, and culture). Concurrent analyses of qualitative and quantitative data will allow insightful integration and triangulation of findings across the study components, allowing us to draw inferences about how youth interact with and manage their lived environments, and what that means for their physical activity and wellbeing [89,90].

Ethics and dissemination

All adolescents will be required to provide assent to participate in the study. An information sheet will be designed specifically for adolescents in a manner that it will be easy to understand. Additionally, all parents of the assenting adolescents will be required to provide parental consent. Parents will also receive a detailed information sheet outlining the study and its requirements.

Data will be entered and stored into a secure (password protected) database. Only the named researchers will have access to the data. Data will be stored for 10 years and permanently destroyed thereafter.

It is unlikely that participants will experience discomfort or embarrassment during data collection. However, as body measures of weight and height will be objectively assessed, there is the potential of concern around body weight and size. The institution's counselling services will be accessed if a situation arises. All body measurements will be taken behind a portable screen with gender appropriate research officers. All data will be kept private and confidential.

At the completion of the study, results will be provided to key stakeholders and organisations (e.g., high schools, adolescents, and parents). Results will be disseminated by means of a written report to schools that have participated in the study. Adolescents and/or their parents/legal guardians will receive a report detailing the individual results collected.

Government organizations, health boards, and councils, will be able to access key findings and recommendations resulting from the project through seminar presentations and report distribution. Research findings will also be circulated to the scientific community in the form publications in refereed journals.

Discussion

We have described the methods for the BEANZ study which seeks to estimate strengths of association between objective measures of the local environment with accelerometer-derived and self-reported physical activity and sedentary behaviour in youth. A novel aspect of this study is the exploration of detailed and multilevel relationships of interaction between the social and physical environments specific to the NZ adolescents. This will be achieved through additional measures (e.g., GPS, VERITAS, focus groups, NDAI) which collectively serve to advance knowledge in this important area of health research, policy advocacy, and ultimately youth health outcomes. Particularly, the use of GPS/VERITAS to identify the locations that adolescents visit on a daily basis, defining their geographical context, will provide us with accurate estimates of location in which physical activity takes place.

International evidence shows that the most consistent environmental attributes positively associated with reported physical activity in youth were land use mix and residential density, but inconsistent findings have been observed for parks, recreation facilities, and street connectivity [41]. Others found that proximity to parks, recreation facilities and proximity to school [32,43,91,92] along with transport infrastructure were positively associated with physical activity in adolescents [92]. Traffic hazards (number of roads to cross, traffic speed) and local conditions (crime, area deprivation) were negatively associated with physical activity [44,92]. Obesogenic environmental attributes of homes, neighborhoods, and schools are believed to promote sedentary behaviour among youth [93] and there is growing evidence that being socially connected with others contributes to adolescent wellbeing [46]. While some evidence exists to show the importance of the built environment for adolescent physical activity and well-being, the use of different methods and limited physical variability within any given environment may serve to consistently underestimate the associations observed. In this study, variance is maximised in two ways. Two major cities in New Zealand are sampled, and these data are subsequently combined with nine other countries through the IPEN-Adolescent study. The larger study will improve our understanding of the nature of the relationships that exist between adolescent physical activity, sedentary behaviour and body weight with specific features of the built environment related to walkability, commuting and access to facilities for recreation.

Individuals (or at least parents) may self-select neighborhoods, therefore associations between built environment and walkability may in part be a reflection of neighborhood self-selection bias. Mixed results have been found when investigating neighborhood self-selection and walkability [94-98]. The relationship is a complex one and prospective studies are needed to study the effects of neighborhood self-selection on neighborhood walkability. When reviewing 38 empirical studies that used different approaches to explore the influence of self-selection, Cao and colleagues [99] established that all studies reviewed found a statistically significant influence of the built environment after accounting for self-selection. While exploring this particular relationship is not the focus of the present study, parents' neighborhood preference and self-selection will be accounted for in the analysis.

When conducting spatial analyses on aggregated data, errors affecting the validity of results may be introduced [100]. The problem has been referred to as the Modifiable Areal Unit Problem defined as the 'geographic manifestation of the ecological fallacy in which conclusions based on data aggregated to a particular set of districts may change if one aggregates the same underlying data to a different set of districts' [101]. In other words, the way spatial data are aggregated may result in different findings. There has been disagreement in the literature on the best solution for this problem; however, it has been suggested that the only appropriate resolution is to use individual-level data that are geocoded based on residential location [102]. Indeed, our selection strategy uses geo-coded data and we are employing techniques (GPS and VERITAS) to gain a more accurate understanding of neighborhood boundaries for youth. This will substantially advance our knowledge in this field.

This study will contribute to national and international scientific knowledge by forming the NZ arm of the international IPEN-Adolescents collaboration, whereby adolescents' physical activity and sedentary behaviour data are collected using a common methodology across multiple countries (Australia, Belgium, Brazil, China, Denmark, Malaysia, New Zealand, Portugal and USA). Furthermore the larger study will improve our understanding of the nature of the relationships that exist between adolescent physical activity, sedentary behaviour and body weight with specific features of the built environment related to walkability, commuting and access to facilities for recreation.

Ultimately, by showing the relationships between health outcomes and the neighborhood built environment, we aim to influence and inform policy and city planning practices. City planners, policy makers and government agencies will be engaged early [103] [104]. Results will also be shared with other sustainable transport advocacy, urban planners, and public health organisations. Dissemination of findings to NZ secondary schools and students themselves will maximise the potential impact of the findings.

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Authors' contributions

EH developed the first draft of the manuscript. EH, SD, MO, SM, EC, HB, VI, JM, and GS contributed to the conception and the design of the study. All authors provided feedback during manuscript development. Each author has read and approved the final manuscript.

Competing interests

The authors declare that they have no competing interests.

References

1. Department of Health Physical Activity Health Improvement and Protection. At least five a week: Evidence on the impact of physical activity and its relationship to health. A report from the Chief Medical Officer. London: Department of Health, 2004.
2. Department of Health Physical Activity Health Improvement and Protection. Start Active, Stay Active: A report on physical activity for health from the four home countries' Chief Medical Officers. London: Department of Health, Physical Activity, Health Improvement and Protection, 2011.
3. Ministry of Health. DHB toolkit: Physical activity. Wellington: Ministry of Health, 2003.
4. U.S. Department of Health and Human Services. Physical Activity and Health: A Report of the Surgeon General. Atlanta, GA: Center for Disease Control and Prevention, 2002.
5. World Health Organization. Global recommendations on physical activity for health. Geneva: World Health Organization, 2010.
6. Janssen I, LeBlanc AG. Review Systematic review of the health benefits of physical activity and fitness in school-aged children and youth. *Int J Behav Nutr Phys Act* 2010;**7**:40.
7. Strong W, Malina R, Blimkie C, et al. Evidence based physical activity for school aged youth. *J Pediatr* 2005;**146**:732-37.
8. Brownson RC, Boehmer TK, Luke DA. Declining rates of physical activity in the United States: what are the contributors? *Annu Rev Public Health* 2005;**26**:421-43.
9. Dumith SC, Gigante DP, Domingues MR, Kohl HW. Physical activity change during adolescence: a systematic review and a pooled analysis. *Int J Epidemiol* 2011;**40**(3):685-98.
10. Matthews, Chen, Freedson, et al. Amount of time spent in sedentary behaviors in the United States, 2003–2004. *Am J Epidemiol* 2007;**167**(7):875-81 doi: 10.1093/aje/kwm390 published.
11. Mitchell J, Pate R, Beets M, Nader P. Time spent in sedentary behavior and changes in childhood BMI: a longitudinal study from ages 9 to 15 years. *Int J Obes* 2012;**37**(1):54-60.

12. Maddison R, Turley M, Legge N, Mitchelhill G. A National Survey of Children and Young People's Physical Activity and Dietary Behaviours in New Zealand: 2008/09. Auckland: Clinical Trials Research Unit, The University of Auckland, 2010.

13. Hamilton, Healy, Dunstan, Zedric, Owen. Too little exercise and too much sitting: Inactivity physiology and the need for new recommendations on sedentary behavior *Curr Cardiovasc Risk Rep* 2008;**2**(4):292-98 doi: 10.1007/s12170-008-0054-8published.

14. Hamilton M, Hamilton D, Zderic W. Exercise physiology versus inactivity physiology: an essential concept for understanding lipoprotein lipase regulation. *Exerc Sport Sci Rev* 2004;**32**:161-66.

15. Hamilton MT, Hamilton DG, Zderic TW. Role of low energy expenditure and sitting in obesity, metabolic syndrome, type 2 diabetes, and cardiovascular disease. *Diabetes* 2007;**56**(11):2655-67.

16. Telama R, Yang X, Viikari J, Välimäki I, Wanne O, Raitakari O. Physical activity from childhood to adulthood: a 21-year tracking study. *Am J Prev Med* 2005;**28**(3):267-73.

17. Hancox RJ, Milne BJ, Poulton R. Association between child and adolescent television viewing and adult health: a longitudinal birth cohort study. *Lancet* 2004;**364**(9430):257-62.

18. Reilly JJ, McDowell ZC. Physical activity interventions in the prevention and treatment of paediatric obesity: systematic review and critical appraisal. *Proc Nutr Soc* 2003;**62**(3):611-20.

19. Dobbins M, De Corby K, Robeson P, Husson H, Tirilis D. School-based physical activity programs for promoting physical activity and fitness in children and adolescents aged 6-18. *Cochrane Database Syst Rev* 2009;**1**(1):1-106 doi: 10.1002/14651858.CD007651published.

20. Summerbell C, Waters E, Edmunds L, Kelly S, Brown T, Campbell K. Interventions for preventing obesity in children. *Cochrane Database Syst Rev* 2005;**3**(3):1-86.

21. King AC, Stokols D, Talen E, Brassington GS, Killingsworth R. Theoretical approaches to the promotion of physical activity: forging a transdisciplinary paradigm. *Am J Prev Med* 2002;**23**(2S):15-25.

22. Giles-Corti B, Timperio A, Bull F, Pikora T. Understanding physical activity environmental correlates: increased specificity for ecological models. *Exerc Sport Sci Rev* 2005;**33**(4):175-81.

23. Hinckson EA, Garrett N, Duncan JS. Active commuting to school in New Zealand Children (2004-2008): A quantitative analysis. *Prev Med* 2011;**52**:332-36.

24. Witten K, Blakely T, Bagheri N, et al. Neighborhood built environment and transport and leisure physical activity: findings using objective exposure and outcome measures in New Zealand. *Environ Health Perspect* 2012;**120**(7):971–77.

25. Conn VS, Hafdahl AR, Mehr DR. Interventions to increase physical activity among healthy adults: meta-analysis of outcomes. *Am J Public Health* 2011;**101**(4):751-58.

26. Metcalf B, Henley W, Wilkin T. Effectiveness of intervention on physical activity of children: systematic review and meta-analysis of controlled trials with objectively measured outcomes (EarlyBird 54). *BMJ: British Medical Journal* 2012;**345**:1-11.

27. De Bourdeaudhuij I, Sallis JF, Saelens BE. Environmental correlates of physical activity in a sample of Belgian adults. *Am J Health Promot* 2003;**18**(1):83-92.

28. Sallis JF, Bowles HR, Bauman A, et al. Neighborhood environments and physical activity among adults in 11 countries. *Am J Prev Med* 2009;**36**(6):484-90.

29. Sallis JF, Glanz K. The role of built environments in physical activity, eating, and obesity in childhood. *The Future of Children* 2006;**16**(1):89-108.

30. Ding D, Sallis JF, Norman GJ, et al. Community food environment, home food environment, and fruit and vegetable intake of children and adolescents. *J Nutr Edu Behav* 2011;**44**(6):634–38.

31. Davison KK, Lawson CT. Do attributes in the physical environment influence children's physical activity? A review of the literature. *Int J Behav Nutr Phys Act* 2006;**3**(1):19.

32. Rodríguez DA, Cho G-H, Evenson KR, et al. Out and about: association of the built environment with physical activity behaviors of adolescent females. *Health & Place* 2012;**18**(1):55-62.

33. McDonald K, Hearst M, Farbakhsh K, et al. Adolescent physical activity and the built environment: a latent class analysis approach. *Health & Place* 2012;**18**(2):191-98.

34. Casey R, Chaix B, Weber C, et al. Spatial accessibility to physical activity facilities and to food outlets and overweight in French youth. *Int J Obes* 2012;**36**(7):914-19.

35. Yin L, Raja S, Li X, Lai Y, Epstein L, Roemmich J. Neighborhood for playing: using GPS, GIS and accelerometry to delineate areas within which youth are physically active. *Urban Studies* 2013:1-18.

36. Laxer RE, Janssen I. The proportion of youths' physical inactivity attributable to neighborhood built environment features. *Int J Health Geogr* 2013;**12**(1):31.

37. Lake A, Townshend T. Exploring the built environment, physical activity and related behaviours of young people attending school, college and those not in employment. *J Public Health* 2013;**35**(1):57-66.

38. Kasehagen L, Busacker A, Kane D, Rohan A. Associations between neighborhood characteristics and physical activity among youth within rural–urban commuting areas in the US. *Matern Child Health J* 2012;**16**(2):258-67.

39. Hobin E, Leatherdale S, Manske S, Dubin J, Elliott S, Veugelers P. A multilevel examination of factors of the school environment and time spent in moderate to vigorous physical activity among a sample of secondary school students in grades 9–12 in Ontario, Canada. *Int J Public Health* 2012;**57**(4):699-709.

40. Badland HM, Schofield GM, Witten K, et al. Understanding the Relationship between Activity and Neighborhoods(URBAN) Study: research design and methodology. *BMC Public Health* 2009;**9**(1):224.

41. Ding D, Sallis JF, Kerr J, Lee S, Rosenberg DE. Neighborhood environment and physical activity among youth: a review. *Am J Prev Med* 2011;**41**(4):442-55.

42. Yin L, Raja S, Li X, Lai Y, Epstein L, Roemmich J. Neighborhood for playing: using GPS, GIS and accelerometry to delineate areas within which youth are physically active. *Urban Studies* 2013.

43. Slater S, Fitzgibbon M, Floyd MF. Urban adolescents' perceptions of their neighborhood physical activity environments. *Leisure Sciences* 2013;**35**(2):167-83.

44. Kann L. Obesity and other correlates of physical activity and sedentary behaviors among US high school students. *J Obes* 2013;**2013** doi: http://dx.doi.org.ezproxy.aut.ac.nz/10.1155/2013/276318published.

45. Moore JB, Brinkley J, Crawford TW, Evenson KR, Brownson RC. Association of the built environment with physical activity and adiposity in rural and urban youth. *Prev Med* 2012;**56** (2013):145–48.

46. Jose PE, Pryor J. New Zealand youth benefit from being connected to their family, school, peer group and community. *Youth Studies Australia* 2010;**29**(4):30-37.

47. Vandenbroucke JP, Von Elm E, Altman DG, et al. Strengthening the Reporting of Observational Studies in Epidemiology (STROBE): explanation and elaboration. *PLoS medicine* 2007;**4**(10):e297.

48. Statistics New Zealand. Subnational population estimates at 30 June 2012. Wellington: Statistics New Zealand, 2013.

49. Demographia. Demographia World Urban Areas: 9th Annual Edition (2013.03). Belleville, Illinois: Demographia, 2013.

50. Frank L, Kerr J, Chapman J, Sallis J. Urban form relationships with walk trip frequency and distance among youth. *Am J Health Promot* 2007;**21**(4):S1-S7.

51. Frank LD, Sallis JF, Saelens BE, et al. The development of a walkability index: application to the Neighborhood Quality of Life Study. *Br J Sports Med* 2010;**44**(13):924-33.

52. Witten K, Pearce J, Day P. Neighborhood Destination Accessibility Index: A GIS tool for measuring infrastructure support for neighborhood physical activity. *Environment and Planning-Part A* 2011;**43**(1):205.

53. Sallis J, Kerr J, Conway J. TEAN (Teen Environment and Neighborhood) study (Unpublished). San Diego: Unversity of California San Diego, 2007-2011.

54. Leslie E, Coffee N, Frank L, Owen N, Bauman A, Hugo G. Walkability of local communities: using geographic information systems to objectively assess relevant environmental attributes. *Health & Place* 2007;**13**(1):111-22.

55. Kerr J, Sallis JF, Owen N, De Bourdeaudhuij I, Cerin E, Reis R. Advancing science and policy through a coordinatediInternational study of physical activity and built environments: IPEN methods. *J Phys Act Health* 2012;**10**(4):581-601.

56. de Vries SI, Bakker I, Hopman-Rock M, Hirasing RA, van Mechelen W. Clinimetric review of motion sensors in children and adolescents. *J Clin Epidemiol* 2006;**59**(7):670-80.

57. Trost SG, Pate RR, Freedson PS, Sallis JF, Taylor WC. Using objective physical activity measures with youth: how many days of monitoring are needed? *Med Sci Sports Exerc* 2000;**32**(2):426-31.

58. Oliver M, Witten K, Kearns R, et al. Kids in the City Study: research design and methodology. *BMC public health* 2011;**11**(1):587.

59. Choi L, Liu Z, Matthews CE, Buchowski MS. Validation of accelerometer wear and nonwear time classification algorithm. *Med Sci Sports Exerc* 2011;**43**(2):357-64.

60. Evenson KR, Catellier DJ, Gill K, Ondrak KS, McMurray RG. Calibration of two objective measures of physical activity for children. *J Sports Sci* 2008;**26**(14):1557-65.

61. Trost SG, Loprinzi PD, Moore R, Pfeiffer KA. Comparison of accelerometer cut points for predicting activity intensity in youth. *Med Sci Sports Exerc* 2011;**43**(7):1360-68.

62. Cole T, Flegal KM, Nicholls D, Jackson AA. Body mass index cut offs to define thinness in children and adolescents: international survey. *BMJ* 2007;**335**(7612):194 doi: 10.1136/bmj.39238.399444published.

63. Inagami S, Cohen DA, Finch BK. Non-residential neighborhood exposures suppress neighborhood effects on self-rated health. *Soc Sci Med* 2007;**65**(8):1779-91.

64. Cummins S. Commentary: investigating neighborhood effects on health—avoiding the 'local trap'. *Int J Epidemiol* 2007;**36**(2):355-57.

65. Kwan M-P. The uncertain geographic context problem. *Ann Assoc Am Geogr* 2012;**102**(5):958-68.

66. Chaix B, Méline J, Duncan S, et al. GPS tracking in neighborhood and health studies: A step forward for environmental exposure assessment, a step backward for causal inference? *Health & Place* 2013;**21**:46-51.

67. Golledge RG, Stimson RJ. Spatial Behavoir: A Geographical Perspective. New York: Guilford Press 1997.

68. Chaix B, Bean K, Leal C, et al. Individual/Neighborhood social factors and blood pressure in the RECORD cohort study which risk factors explain the associations? *Hypertension* 2010;**55**(3):769-75.

69. Chaix B, Billaudeau N, Thomas F, et al. Neighborhood effects on health: correcting bias from neighborhood effects on participation. *Epidemiology* 2011;**22**(1):18-26.

70. Chaix B, Kestens Y, Perchoux C, Karusisi N, Merlo J, Labadi K. An interactive mapping tool to assess individual mobility patterns in neighborhood studies. *Am J Prev Med* 2012;**43**(4):440-50.

71. Havard S, Reich BJ, Bean K, Chaix B. Social inequalities in residential exposure to road traffic noise: an environmental justice analysis based on the RECORD Cohort Study. *Occup Environ Med* 2011;**68**(5):366-74.

72. Duncan S, Stewart TI, Oliver M, et al. Portable Global Positioning System receivers: Static validity and environmental conditions. *Am J Prev Med* 2013;**44**(22):e19-e29.

73. Kerr J, Duncan S, Schipperjin J. Using Global Positioning Systems in health research: a practical approach to data collection and processing. *Am J Prev Med* 2011;**41**(5):532-40.

74. Brownson RC, Hoehner CM, Day K, Forsyth A, Sallis JF. Measuring the built environment for physical activity: State of the science. *Am J Prev Med* 2009;**36**(4):S99-S123. e12.

75. De Bourdeaudhuij I, Sallis JF, Saelens BE. Environmental correlates of physical activity in a sample of Belgian adults. *Am J Health Promot* 2003;**18**(1):83-92.

76. Leslie E, Saelens BE, Frank LD, et al. Residents' perceptions of walkability attributes in objectively different neighborhoods: A pilot study. *Health & Place* 2005;**11**(3):227-36.

77. Saelens BE, Sallis JF, Black JB, Chen D. Neighborhood-based differences in physical activity: An environment scale evaluation. *Am J Public Health* 2003;**93**(9):1552-58.

78. Cerin E, Conway TL, Cain KL, et al. Sharing good NEWS across the world: developing comparable scores across 12 countries for the neighborhood environment walkability scale (NEWS). *BMC Public Health* 2013;**13**(1):309.

79. Rosenberg D, Ding D, Sallis JF, et al. Neighborhood Environment Walkability Scale for Youth (NEWS-Y): reliability and relationship with physical activity. *Prev Med* 2009;**49**(2):213-18.

80. Van Der Horst K, Paw MJCA, Twisk JWR, Van Mechelen W. A brief review on correlates of physical activity and sedentariness in youth, 2007:1241.

81. Norman GJ, Schmid BA, Sallis JF, Calfas KJ, Patrick K. Psychosocial and environmental correlates of adolescent sedentary behaviors. *Pediatrics* 2005;**116**(4):908.

82. Duncan JS, Hopkins WG, Schofield G, Duncan EK. Effects of weather on pedometer-determined physical activity in children. *Med Sci Sports Exerc* 2008;**40**(8):1432.

83. Goldstein H, Browne W, Rasbash J. Multilevel modelling of medical data. *Stat Med* 2002;**21**(21):3291-315.

84. Burton P, Gurrin L, Sly P. Tutorial in biostatistics. Extending the simple linear regression model to account for correlated responses: an introduction to generalized estimating equations and multi-level mixed modeling. *Stat Med* 1998;**17**:1261-91.

85. Browne WJ, Draper D. A comparison of Bayesian and likelihood-based methods for fitting multilevel models. *Bayesian Analysis* 2006;**1**(3):473-514.

86. Austin PC. Estimating Multilevel Logistic Regression Models when the number of clusters is low: a comparison of different statistical software procedures. *Int J Biostats* 2010;**6**(1):1557-4679 doi: 10.2202/1557-4679.1195published.

87. Marrie RA, Dawson NV, Garland A. Quantile regression and restricted cubic splines are useful for exploring relationships between continuous variables. *J Clin Epidemiol* 2009;**62**(5):511-17. e1.

88. Attride-Stirling J. Thematic networks: an analytic tool for qualitative research. *Qual Res* 2001;**1**(3):385-405.

89. Östlund U, Kidd L, Wengström Y, Rowa-Dewar N. Combining qualitative and quantitative research within mixed method research designs: A methodological review. *Int J Nurs Stud* 2011;**48**(3):369.

90. Tashakkori A, Teddlie C. Handbook of mixed methods in social & behavioral research: Sage Publications, Inc, 2003.

91. Cohen DA, Ashwood S, Scott M, et al. Proximity to school and physical activity among middle school girls: the trial of activity for adolescent girls study. *Pediatrics* 2006;**118**(5):e1381.

92. Davison K, Lawson C. Do attributes in the physical environment influence children's physical activity? A review of the literature. *Int J Behav Nutr Phys Act* 2006;**3**(1):19.

93. Giles-Corti B, Kelty SF, Zubrick SR, Villanueva KP. Encouraging walking for transport and physical activity in children and adolescents. *Sports Med* 2009;**39**(12):995-1009.

94. Owen N, Cerin E, Leslie E, et al. Neighborhood walkability and the walking behavior of Australian adults. *Am J Prev Med* 2007;**33**(5):387-95.

95. Boarnet MG, Sarmiento S. Can land-use policy really affect travel behaviour? A study of the link between non-work travel and land-use characteristics. *Urban Studies* 1998;**35**(7):1155-69.

96. Cao X, Handy SL, Mokhtarian PL. The influences of the built environment and residential self-selection on pedestrian behavior: evidence from Austin, TX. *Transportation* 2006;**33**(1):1-20.

97. Handy S, Cao X, Mokhtarian PL. Self-selection in the relationship between the built environment and walking: Empirical evidence from Northern California. *J Am Plann Assoc* 2006;**72**(1):55-74.

98. Frank LD, Saelens BE, Powell KE, Chapman JE. Stepping towards causation: do built environments or neighborhood and travel preferences explain physical activity, driving, and obesity? *Soc Sci Med* 2007;**65**(9):1898-914.

99. Cao X, Mokhtarian PL, Handy SL. Examining the impacts of residential self-selection on travel behaviour: a focus on empirical findings. *Transport Reviews* 2009;**29**(3):359-95.

100. Yang T-C. Modifiable areal unit problem. *GIS Resource Document* 2005.

101. Waller LA, Gotway CA. Applied spatial statistics for public health data: John Wiley & Sons, 2004.

102. Weeks JR. The role of spatial analysis in demographic research. *Spatially integrated social science* 2004:381-99.

103. McCann B. Making physical activity research relevant to policy makers. *J Phys Act Health* 2006;**3**(Supp1):S267-S72.

104. Brownson RC, Jones E. Bridging the gap: translating research into policy and practice. *Prev Med* 2009;**49**(4):313-15.

STROBE Statement—Checklist of items that should be included in reports of ***cross-sectional studies***

	Item No	Recommendation
Title and abstract	1	✓ (*a*) Indicate the study's design with a commonly used term in the title or the abstract
		✓ (*b*) Provide in the abstract an informative and balanced summary of what was done and what was found
Introduction		
Background/rationale	2	✓ Explain the scientific background and rationale for the investigation being reported
Objectives	3	✓ State specific objectives, including any prespecified hypotheses
Methods		
Study design	4	✓ Present key elements of study design early in the paper
Setting	5	✓ Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection
Participants	6	✓ (*a*) Give the eligibility criteria, and the sources and methods of selection of participants
Variables	7	✓ Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable
Data sources/ measurement	8*	✓ For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group
Bias	9	✓ Describe any efforts to address potential sources of bias
Study size	10	✓ Explain how the study size was arrived at
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why
Statistical methods	12	✓ (*a*) Describe all statistical methods, including those used to control for confounding
		(*b*) Describe any methods used to examine subgroups and interactions
		(*c*) Explain how missing data were addressed
		(*d*) If applicable, describe analytical methods taking account of sampling strategy
		(*e*) Describe any sensitivity analyses
Results		
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed
		(b) Give reasons for non-participation at each stage
		(c) Consider use of a flow diagram
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders
		(b) Indicate number of participants with missing data for each variable of interest
Outcome data	15*	Report numbers of outcome events or summary measures
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included
		(*b*) Report category boundaries when continuous variables were categorized
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a

		meaningful time period
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses
Discussion		
Key results	18	✓ Summarise key results with reference to study objectives
Limitations	19	✓ Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence
Generalisability	21	✓ Discuss the generalisability (external validity) of the study results
Other information		
Funding	22	✓ Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based

*Give information separately for exposed and unexposed groups.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

BUILT ENVIRONMENT AND PHYSICAL ACTIVITY IN NEW ZEALAND ADOLESCENTS: A PROTOCOL FOR A CROSS SECTIONAL STUDY

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BUILT ENVIRONMENT AND PHYSICAL ACTIVITY IN NEW ZEALAND ADOLESCENTS: A PROTOCOL FOR A CROSS SECTIONAL STUDY

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Abstract

Introduction: Built-environment interventions have the potential to provide population-wide effects and provide the means for a sustained effect on behavior change. Population-wide effects for adult physical activity have been shown with selected built environment attributes; however, the association between the built environment and adolescent health behaviors is less clear. This New Zealand study is part of an international project across 10 countries (International Physical Activity and the Environment Network– Adolescents) that aims to characterize the links between built environment and adolescent health outcomes.

Methods and Analyses: An observational, cross-sectional study of the associations between measures of the built environment with physical activity, sedentary behavior, body size, and social connectedness in 1,600 New Zealand adolescents aged 12-18 years will be conducted in 2013-2014. Walkability and neighborhood destination accessibility indices will be objectively measured using Geographic Information Systems (GIS). Physical activity and sedentary behaviors will be objectively measured using accelerometers over seven consecutive days. Body mass index will be calculated as weight divided by squared height. Demographics, socioeconomic status, active commuting behaviors, and perceived neighborhood walkability will be assessed using the Neighborhood Environment Walkability Scale for Youth and psychosocial indicators. A web-based computer-assisted personal interview (CAPI) tool (VERITAS) and Global Positioning System (GPS) receivers will be used in a subsample of 300 participants. A qualitative research component will explore barriers and facilitators for physical activity in adolescents with respect to the built and social environment in a subsample of 80 participants.

Ethics and dissemination: The study received ethical approval from the Auckland University of Technology Ethics Committee (12/161). Data will be entered and stored into a secure (password protected) database. Only the named researchers will have access to the data. Data will be stored for 10 years and permanently destroyed thereafter. The results papers will be submitted for publication in peer-reviewed journals.

Strengths and limitations of this study

- Limited data exists on detailed and multilevel relationships of interaction between the social and physical environments specific to the NZ adolescents.
- The use of GPS/VERITAS will define the adolescents' geographical context and will provide accurate estimates of location in which physical activity takes place.
- The study forms the NZ arm of the international IPEN-Adolescents collaboration, whereby adolescents' physical activity and sedentary behavior data are collected using a common methodology across multiple countries.
- Parents may self-select neighborhoods, therefore associations between built environment and walkability may in part be a reflection of neighborhood self-selection bias. Parents' neighborhood preference and self-selection will be accounted for in the analysis.
- When conducting spatial analyses on aggregated data, errors affecting the validity of results may be introduced. Geo-coded data and other techniques will assist in gaining a more accurate understanding of neighborhood boundaries for adolescents.

Built environment and physical activity in New Zealand adolescents: A cross sectional study

Introduction

The benefits of physical activity in youth are well documented [1-5]. Regular moderate-to-vigorous physical activity (MVPA) is positively associated with musculoskeletal health, cardiovascular wellbeing (e.g., healthy blood pressure, lipid and lipoprotein levels, cardiovascular autonomic tone), metabolic health, maintenance of a healthy weight, psychological wellbeing (e.g., improved self-concept, reduced anxiety and depression), and reduced risk of type 2 diabetes [6,7]. The accumulation of at least 60 minutes of MVPA per day is recommended for youth; however, accumulating physical activity below this threshold is still beneficial, especially for those whose health is at risk (e.g., overweight or obese youth) [6]. Despite awareness of the well-established benefits of physical activity, rapid changes in technology and the habitual environment over the last 50 years may have caused an increase in sitting, passive travel, and subsequently a reduction in incidental physical activity [8]. Furthermore, over the course of adolescence, physical activity typically decreases by 60-70% [9], while sedentary behavior remains high at 7-14 hours per day [10-12]. The latter trend is particularly concerning given that emerging evidence suggests that sedentary behavior has negative effects on health that are independent of the beneficial effects of physical activity [13-15]. Additionally, levels of activity during school age years significantly predict activity levels [16] and health outcomes [17] into adulthood.

Behavioral modification programmes have only achieved limited and mostly short term physical activity improvements [18-20]. For sustainable changes that optimise positive behaviors, it is important to understand that physical activity and sedentary behaviors occur within a broader ecological framework [21]. It is recognised that in order to be effective, complex integrated interventions are required that include supportive policies and social and physical environments [22,23]. Manipulating social and physical environments to be more health promoting will likely have sustainable and far-reaching impacts on population health behaviors and outcomes. We have previously examined the relationship of objective built environment measures (i.e., destination access, street connectivity, dwelling density, land use mix) with accelerometer-derived and self-reported physical activity in adults [24]. The work was part of a larger international study (IPEN-International Physical activity and Environment Network) with 12 participating countries. The potential of walkable neighborhoods for supporting health-enhancing increases in physical activity, at least for adults, was high [24]. A one standard deviation increase in neighborhood walkability variables yielded a 7-13% increase in physical activity. This effect is likely to be much higher than effects achieved through behavioral intervention alone [25,26].

While the evidence base for associations between the built environment and physical activity in adults has been steadily accumulating [24,27,28], our understanding of this relationship in adolescents is at its infancy [29-38], and at times non-intuitive [33,39]. Adolescents were consistently identified in our adult focus groups in our previous study as a sub-group whose changing needs for independent mobility and age- and culturally-appropriate forms of physical activity are less likely to be met, particularly in more suburban built environment forms [40]. In a recent review, land-use mix and residential density were the most highly correlated built environment variables with overall physical activity in youth [41]. However,

the review did not find any environmental variables that consistently correlated with physical activity in adolescents. Nonetheless, latest research indicates that adolescents' physically activity tends to occur close to their homes [42,43], and that strong associations exist between inactivity with lower neighborhood walkability, amount of public open space, and neighborhood safety [44], as well as higher densities of cul-de-sac networks [36]. MVPA is significantly lower for rural adolescents compared to those living in urban environments, however these differences between neighborhood type are not seen for BMI [45]. Geospatial data indicate that adolescent girls engage in higher intensity physical activity in places with parks, schools, and higher population density, and accumulate lower levels of physical activity in places with more roads and food outlets [32]. Low-income adolescents were physically active at fields/courts, indoor recreation facilities, small and large parks, and swimming pools [43] but reduced accessibility of physical activity facilities and food outlets was associated with being overweight [34].

In the Built Environment and Adolescent New Zealanders (BEANZ) study, we seek to understand the relationship of physical activity, sedentary behavior, and body size with neighborhood-level built environment features in New Zealand (NZ) adolescents. We hypothesise that neighborhood walkability and neighborhood destination accessibility indices will be positively associated with minutes of MVPA, and inversely associated with minutes of sedentary time and body mass index (BMI). We will also investigate associations between the built environment and social connectedness to the community [46], the moderating effects of ethnicity and mediating effects of active commuting, neighborhood mobility, and perceived neighborhood walkability. A novel aspect of this study is the use of portable global positioning system (GPS) receivers together with web-based interactive mapping and geocoding software to examine adolescents' mobility and access to regular destinations. These ancillary data will enable the shape and scale of environmental exposure to be defined in considerable detail.

Our study forms part of the IPEN-Adolescent collaboration, using comparable data collection, management, and protocol sharing across 10 countries. By comparing diverse countries, built environmental heterogeneity can be captured (and therefore generate robust estimates of the real effects) while facilitating intra- and inter-country comparisons. The goal is to generate credible evidence to guide long-term town planning, policy change, and redesign of existing urban environments to maximise physical activity and community connectedness and minimise sedentary behavior and body size, all key determinants of human health.

Method and analysis

The standardized checklist for the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) recommendations was used to ensure that all elements recommended were address within this section [47].

Design

BEANZ will be based on an observational, cross-sectional design that examines the associations of objective and subjective measures of the built environment with physical activity, sedentary behavior, body size, and social connectedness in 1,600 NZ adolescents aged 12-18 years from eight secondary schools (approximately 200 participants per school). Moreover, differences between non-Māori and Māori population groups will be explored.

Demographics, socioeconomic status, active commuting, psychosocial indicators, and perceptions of the built environment will be measured in the full sample. Data will be collected in the 2013-2014 academic school years for the southern hemisphere. A GPS and interactive mapping sub-study of approximately 300 participants will assess neighborhood mobility by geolocating participants' destinations, modes of travel, activity locations, walking/cycling area, and perceived neighborhood boundaries. Focus groups will explore barriers and facilitators for physical activity with respect to neighborhood built and social environment in a subsample of approximately 80 participants. Data will be collected from two major cities in New Zealand: Auckland and Wellington. Auckland is the largest city in New Zealand with a population of approximately 1.4 million residents (one third of the country's population) [48], with a population density comparable to Los Angeles and Helsinki [49]. Wellington, the capital city of New Zealand, is located on the southern part of the North Island and has a population density comparable to Vancouver and Honolulu [49]. Ethical approval was received by the Institution's Ethics Committee (AUTEC, 12/161).

Neighborhood, school and participant selection

Associations between exposure and outcome variables are estimated based on data collected using a multistage sampling strategy. This strategy maximises heterogeneity in the exposure variables (built environment) while allowing comparisons to be made between those of low and high socioeconomic status (SES). In the first instance, GIS will be used to calculate three built environment measures – street connectivity, residential density, and land use mix –for each meshblock (smallest census tract units available in New Zealand) [40]. Street connectivity will be calculated by dividing the number of 3-or-more-way intersections by the area in square kilometres. To avoid edge effects associated with meshblocks delineated by street centrelines, street connectivity will be calculated for 20 m meshblock buffers. Intersections will be extracted from 2013 street network datasets provided by territorial authorities. Residential density will be calculated by dividing the number of dwellings by the residential land area. The number of dwellings will be obtained from the 2006 census data provided at the meshblock level. Residential land area will be derived from 2013 zoning datasets provided by territorial authorities. Land use mix will be calculated using the area of five land use categories (residential, commercial, industrial, open space, other) in an entropy equation [50]. Land uses will be determined using 2013 zoning datasets provided by territorial authorities. The raw scores for these three built environment measures will be normalised (converted to deciles) and summed to create a basic walkability index. This basic meshblock level walkability index will only be used in school and participant selection. The GIS-based built environment indices that will be created for each participant and used in analyses are described in a later section.

The raw scores for these built environment measures will be normalised and summed to create a basic walkability index. Next the basic walkability index and and pre-existing deprivation data (NZ Dep 2006) will be used to classify all Auckland and Wellington urban meshblocks) into one of four strata: (1) higher walkable, higher SES; (2) higher walkable, lower SES; (3) lower walkable, higher SES; and (4) lower walkable, lower SES. Meshblocks with the top four walkability/SES deciles are classified as higher walkable/SES, and meshblocks with the bottom four walkability/SES deciles are classified as lower walkable/SES. Meshblocks with walkability or SES in deciles 5 and 6 are excluded.

School selection will be based on convenience and close proximity to large numbers of meshblocks in each of the four strata. Within each school, all potential participants will be sampled, regardless of the quadrant they reside, and for each participant walkability will be calculated: all students will be assigned to the strata of the meshblock they primarily reside in. This procedure will take place prior to the consent process. Adolescents living in one of the four meshblock strata will be invited to participate in the study. Participation in the study will require written, informed consent from a parent or caregiver and written assent from the adolescent. At the time of consent parents will be asked to rate the importance of a variety of reasons for choosing to live in their neighbourhood. Subsequent schools will be selected on the basis of the quadrants that need to be balanced. In addition to this approach, care will be taken to balance student numbers across the four strata both within and across schools. A similar sampling strategy was used in our previous study of the environmental correlates of physical activity in adults; the heterogeneity generated by this technique permitted several meaningful associations to be detected [40]. A sub-sample of approximately 40 participants will be randomly selected from each school for the GPS and interactive mapping measurements.

Sample size

In adjusted multilevel models, it has been estimated that a sample of 1,600 adolescents recruited from two schools within each stratum (eight in total) would allow the detection of a small effect size (i.e., 1.4% of explained outcome variance found in similar studies conducted elsewhere [51]) with 80% power. The calculated sample size assumes a two-tailed probability level of 5%, a conservative clustering effect equivalent to an intra-class correlation coefficient of 0.10, and a regression model with 25 background covariates explaining 25% of the outcome variance (comparable to what might be expected from the selected variables). With an anticipated sample size of 320 Māori adolescents (our smallest sub-group comparison), the corresponding detectable effect size will be 7% of explained outcome variance (medium effect size).

Exposure, outcomes and covariates

Exposures

GIS data provide multiple spatially-referenced layers that can be used to create meaningful and objective exposure measures of the built environment. They are used to objectively characterise the built environment surrounding the primary home address of each participant and can be applied across a range of road network buffers (e.g., 500 m, 800 m, 1000 m, and 1600 m) in order to evaluate differences between various limits of exposure. Road network buffers can be created to define areas that can be reached on the street network system, but exclude areas that are not accessible due to major barriers (motorway, river, lake). Two main indices, each a composite function of 2-8 other variables, are used to assess physical environmental features: walkability index [52] and neighborhood destination accessibility index [53]. These are described in more detail below. All exposure measures (Table 1) follow the common protocols established for the international IPEN-Adolescents collaboration.

Table 1. Summary of study exposure, outcomes, and covariate

Exposure	**Covariates**
Detailed walkability index	Demographics
- Net residential density	- Age
- Land use mix	- Sex
- Retail density	- Ethnicity
- Street connectivity	- School

- Street discontinuity	Socioeconomic status
Neighborhood destination accessibility index	- Parent education
- Education destinations	- Parent occupation
- Transport destinations	- Family car ownership
- Recreation destinations	- Household crowding
- Social and cultural destinations	Active commuting
- Food retail destinations	- Frequency of active commuting
- Financial destinations	- Duration of active commuting
- Health destinations	Neighborhood mobility
- Other retail	- Frequency and location of regular destinations
Outcomes	- Frequency and location of activity
Physical activity behavior	- Total walking area
- Minutes of MVPA	- Total cycling area
- Minutes of light activity	- Perceived neighborhood boundary
Sedentary behavior	Perceived neighborhood walkability
- Minutes of overall sedentary activity	- Perceived residential density
- Minutes of television watching	- Perceived land use mix
Body size	- Perceived traffic/crime safety
- Body mass index	- Perceived aesthetics
- Waist circumference	Psychosocial indicators
	- Self-efficacy
	- Cons/barriers
	- Family support
	- Peer support
	Weather
	- Total rainfall
	- Mean temperature
	- Hours of daylight

Detailed walkability

The detailed walkability index is a summary score of five distinct variables calculated within GIS: net residential density, land use mix, retail density, street connectivity, and street discontinuity. This protocol was created for the US-based Neighborhood Quality of Life Study project, [52] and has been subsequently implemented in the US-based TEAN study [54], the Australian PLACE study, [50] and all IPEN Adult country study sites [55].

Neighborhood Destination Accessibility

Pedestrian access to destinations will be calculated using the Neighborhood Destination Accessibility Index (NDAI) [53]. The NDAI is an objective measure of pedestrian access to neighborhood destinations; it characterises the distribution of urban infrastructure within an 800m street network distance from residence. The NDAI has an advantage over most previous area-level measures of the urban environment in that it captures the range and intensity of everyday destinations such as schools, supermarkets and cafes, which may encourage active travel and enhance recreational physical activity at the population level. As well, the NDAI has been specifically designed for the New Zealand environment. The eight domains captured in the NDAI are education, transport, recreation and play, social and cultural, food retail, financial, health, and other retail.

Outcomes

Physical Activity

Minutes of MVPA will be objectively measured using hip-mounted triaxial accelerometers (Actigraph GT3X+) over seven consecutive days. The GT3X+ is a small, durable, and water resistant device worn on an elastic belt that records the frequency, duration, and intensity of physical activity with a high level of accuracy and precision [56]. Participants are asked to wear the Actigraph during all waking hours (except when bathing or swimming) for seven days; however, at least five complete days (including at least one weekend day) will be required for analysis to ensure reliable estimates of MVPA [57]. Consistent with previous research, a valid day will be defined as at least 10 hours of data for weekdays and 8 hours for weekend days; non-wear time will be defined as 60 minutes of consecutive zero counts [58,59]. In addition, each participant will be given a seven-day compliance log to complete daily, which assists with identifying non-wear periods. Upon collection of the accelerometer, data are downloaded and screened for completeness and possible malfunction using the Meterplus software (www.meterplussoftware.com). Accelerometer count data will be classified into minutes of light, moderate, and vigorous activity using thresholds developed by Evenson and colleagues [60]; these have performed well in a recent comparison of accelerometer count thresholds for youth [61].

Sedentary Behavior

Minutes of sedentary activity will be objectively assessed using the GT3X+ accelerometer over the seven-day measurement period. The aforementioned cut-points established by Evenson and colleagues [60] will be used to define sedentary time (< 100 counts per minute).

Body Size

Height, weight, and waist circumference of each participant will be measured by trained field researchers using a stadiometer, calibrated scales, and a tape measure. These procedures occur immediately before the researchers distribute the accelerometers; participants wear light clothing and shoes are removed. BMI will be calculated as weight divided by squared height. Participants are classified into weight status categories using age- and sex-specific BMI thresholds [62].

Covariates

Demographics and socioeconomic status

Age, sex, ethnicity, and SES will be collected from the participants. Consistent with the IPEN-adolescents protocol, household income will be the preferred SES indicator, but highest level of parental education will be used when income is unavailable.

Active commuting

The frequency, distance, duration, and mode of all active commuting trips to or from the home address in the previous six months will be assessed with the CAPI. The recall of each trip will be aided by a basic travel log (time, location, and mode of transport only) to be completed nightly with the accelerometer compliance log. Participants will be asked to bring this information with them to the subsequent CAPI.

Neighborhood Mobility

The majority of studies investigating the built environment and health have focused exclusively on residential neighborhoods as a predictor of exposure [63,64], and overlooked the prospect that a large proportion of activity choices may be influenced by additional environments that are experienced during daily routines. This may reduce the accuracy of environmental exposure assessment [65] and introduce errors that may confound research results. It has been suggested that investigating aspects of daily mobility (regular destinations and the movement between them) will be important to enhance the assessment of exposure [66] and resolve the Uncertain Geographic Context Problem [67]. Using GPS and interactive activity destination questionnaires, we aim to accurately capture the full extent of daily mobility, and its mediating built environment effect on health.

The Visualization and Evaluation of Route Itineraries, Travel Destinations, and Activity Spaces (VERITAS) is a web-based CAPI tool integrating interactive mapping capacities (based on Google Maps) and has the potential to explore destinations both inside and outside the residential neighborhood. VERITAS was initially developed and tested for the RECORD Cohort Study, a major longitudinal study of over 7,200 French adults [68-71]. The applicability and feasibility of this method to an adolescent population is detailed elsewhere (manuscript under review but available on request). While we will be using GIS to provide an objective assessment of the surrounding environment (i.e., exposure measures), VERITAS will allow the research team to search and geolocate participants' regular destinations (visited within the previous 6 months), activity locations, walking/cycling area, routes and modes of travel between locations, travel companions, and perceived or experienced neighborhood boundaries (i.e., neighborhood mobility). The VERITAS programme will run through an internet browser on a laptop computer, and will be designed to automatically upload all participant responses to our secure database when connected to a wireless network. Spatio-temporal data will be collected using the Qstarz BT-Q1000XT GPS receiver (Qstarz International, Taipai, Taiwan) which has been deemed one of the more accurate portable GPS receivers on the market [72]. The GPS will be worn in a pouch alongside the accelerometer. GPS data will be cleaned, filtered and merged with accelerometer data using the Personal Activity Location Measurement System (PALMS, refer to: https://ucsd-palms-project.wikispaces.com) [73]. The merged data streams retrieved from PALMS will be disaggregated into discrete trips and imported into ArcGIS for further analysis. Data obtained from GPS and VERITAS differ both temporally (previous 1 week and 6 months, respectively) and spatially (a continuous sequential polyline compared with point data). Although VERITAS will be able to obtain data for extended periods, it lacks the temporal sequence of events available from GPS tracking. However, as short periods of GPS monitoring may not truly represent destinations visited over extended periods, the combination of both has been recommended to create complementary and more robust measures of environmental exposure [70].

The neighborhood mobility data will allow the demarcation of the territorial range by active travel modes. A spatial 'polygon' will be created consisting of a multisided geometric shape surrounding the home address that connects the various locations to which participants claim to have walked or cycled. The area (m^2) within these polygons will be calculated and used to define separate shapes based on the travel modes. In situations where participants walk or cycle to only one location (e.g., school) the polygon area will be the distance between the location and home addresses multiplied by 1 m. As with the active commuting assessment, the recall of visited locations and trips will be aided by the travel log that will be completed daily. Finally, using VERITAS, each participant will be able to map their perceived neighborhood boundary, allowing us to isolate the effects of their self-defined neighborhood environment on the outcome measures.

Perceived Neighborhood Walkability

In order to understand the mediating effect of individual perceptions of the neighborhood on the relationship between the objectively-measured built environment and physical activity behavior, the Neighborhood Environment Walkability Scale for Youth (NEWS-Y) will be administered as a self-completion hard copy survey. NEWS-Y is based on the NEWS, which has demonstrated good reliability and validity [74-78]. In addition to the GIS-based walkability index variables (residential density, land use mix, street connectivity), NEWS-Y assesses pedestrian/cycle facilities, aesthetics, traffic safety, and crime safety. The ten NEWS-Y subscales have acceptable test-retest reliability (ICC: 0.56-0.87) and specific subscales were correlated significantly with physical activity for adolescents [79].

Psychosocial Indicators

A small number of psychosocial variables associated with adolescent physical activity will be measured in the study. These include: self-efficacy; perceived barriers to being physically activity; family support; and peer support [79]. These variables have shown the most consistent psychosocial correlations with adolescent physical activity in the literature [80]. Further, by including such items we are able to examine our findings within a multilevel framework thereby accounting for and separating the various layers of influence (i.e., individual, social, and physical environments) [81].

Self-reported physical activity, sedentary behavior and commuting to school

In addition to perceived neighbourhood walkability and psychosocial indicators, participants will be asked to report on commuting (to and from school, walking and biking, barriers to walking and cycling) [82-84], physical activity (at and outside of school, places for, barriers in the neighbourhood, decisions about, confidence about, enjoyment of, social support, workout equipment, activity rules, and athletic ability) [85-87], and sedentary behavior (during school and weekend days, things in the bedroom and personal electronics) [88]. The scales have shown to be reliable and valid in the adolescent population [82-84,88].

Weather

We have previously demonstrated the significant impact of inclement weather conditions on physical activity in New Zealand children [89]. To monitor these potential confounding effects we will obtain hourly rainfall, mean temperature, and hours of daylight statistics from the New Zealand Met Service for each data collection day and use these as covariates in the models.

Procedures

Data will be collected from participants within the school setting in school hours. During the measurement session, the NEWS-Y [79] questionnaire will be administered, anthropometric measures will be taken and accelerometers and compliance logs will be distributed. Text messages will be sent to adolescents/parents before data collection session as a reminder to attend. A random sub-sample of 40 adolescents per school will be allocated a GPS receiver to wear in conjunction with the accelerometer, and will complete the VERITAS interview. All participants will be instructed on the correct use, wear-time, and care of the equipment. Participants will be issued with a $20 shopping voucher upon completion of data collection and return of the monitors and compliance logs.

Quantitative Analyses

The proposed dataset will have a hierarchical independent variable structure which consists of person-level observations nested within neighborhoods and schools. The main aim of the study is to examine confounder-adjusted associations of environmental variables with physical activity and body size outcomes. For this purpose, cross-classified (by neighborhoods and schools) generalized linear mixed models (MGLM) with random intercepts will be used. These can account for multiple sources of dependency (schools and neighborhoods) and different types of data (e.g., continuous or binary) following a Normal or other types of distributions (e.g., negative binomial, Poisson) [90]. MGLMs perform well when the number of observations across areas is highly unbalanced, [91] which will be relevant to this project as the number of participants may vary substantially across schools and neighborhoods. Given the relatively small number of strata included in the study, MGLMs will be estimated using Restricted Maximum Likelihood (REML) or Bayesian Markov chain Monte Carlo (MCMC) methods with non-informative priors, [92] the latter appropriate for binary (e.g., overweight/obese vs. normal weight) [92,93] or non-normally distributed outcomes [90]. Non-linear relationship will be examined using restricted cubic splines [94]. A probability level of 0.05 will be adopted.

Qualitative Methodology

A total of 16 focus groups, with approximately 5-8 participants, will be conducted at eight participating schools. One researcher (VI) will conduct all the focus groups and at least one of the co-researchers will assist. Variability in walkability will be sought by recruiting two schools in Auckland (representing relatively low walkability) and Wellington (relatively high walkability). However students within focus groups will be selected to represent a range of neighborhood settings to facilitate discussion on differing experiences of the built environment. Participants will also take part in the quantitative component and completed all data collection. To aid open discussion and allow meaningful comparisons separate focus groups will be conducted by age, with younger students (approximately 12-14 years) further stratified by sex, and older students (approximately 15-18 years) in mixed sex groups [43]. Focus groups will be conducted using 40 min school periods to accommodate school timetables semi-structured interview. The focus groups are designed to examine the enablers and barriers to being physically active, particularly with regard to active transport, engagement in formal and informal physical activity, safety, and social drivers. Researchers will specifically seek discussion on activity within participants' residential neighborhood and school environments as well as alternative activity spaces in their everyday lives, including those outside of their geographical suburbs. Maps of local environments to prompt discussion on where youth are active (and where they avoid), types of activity, and travel routes will be used. Interviews will be digitally recorded and transcribed by group, with all individual identifying information removed.

Qualitative Analyses

Initially, two of the researchers will independently read the transcripts, code and extract themes. The themes will be presented to the team. Disagreement will be resolved through discussion and themes will be confirmed. A coding framework will be developed using NVivo software to organise data generated by the project research questions (deductive) and emergent topics (inductive) [95]. Analyses will be conducted across and within groups to examine commonalities and differences by built environment settings and individual factors (i.e., sex, age, and culture). Concurrent analyses of qualitative and quantitative data will allow insightful integration and triangulation of findings across the study components, allowing us to draw inferences about how youth interact with and manage their lived environments, and what that means for their physical activity and wellbeing [96,97].

Ethics and dissemination

All adolescents will be required to provide assent to participate in the study. An information sheet will be designed specifically for adolescents in a manner that it will be easy to understand. Additionally, all parents of the assenting adolescents will be required to provide parental consent. Parents will also receive a detailed information sheet outlining the study and its requirements.

Data will be entered and stored into a secure (password protected) database. Only the named researchers will have access to the data. Data will be stored for 10 years and permanently destroyed thereafter.

It is unlikely that participants will experience discomfort or embarrassment during data collection. However, as body measures of weight and height will be objectively assessed, there is the potential of concern around body weight and size. The institution's counselling services will be accessed if a situation arises. All body measurements will be taken behind a portable screen with gender appropriate research officers. All data will be kept private and confidential.

At the completion of the study, results will be provided to key stakeholders and organisations (e.g., high schools, adolescents, and parents). Results will be disseminated by means of a written report to schools that have participated in the study. Adolescents and/or their parents/legal guardians will receive a report detailing the individual results collected. Government organizations, health boards, and councils, will be able to access key findings and recommendations resulting from the project through seminar presentations and report distribution. Research findings will also be circulated to the scientific community in the form publications in refereed journals.

Discussion

We have described the methods for the BEANZ study which seeks to estimate strengths of association between objective measures of the local environment with accelerometer-derived and self-reported physical activity and sedentary behavior in youth. A novel aspect of this study is the exploration of detailed and multilevel relationships of interaction between the social and physical environments specific to the NZ adolescents. This will be achieved through additional measures (e.g., GPS, VERITAS, focus groups, NDAI) which collectively serve to advance knowledge in this important area of health research, policy advocacy, and ultimately youth health outcomes. Particularly, the use of GPS/VERITAS to identify the locations that adolescents visit on a daily basis, defining their geographical context, will provide us with accurate estimates of location in which physical activity takes place.

International evidence shows that the most consistent environmental attributes positively associated with reported physical activity in youth were land use mix and residential density, but inconsistent findings have been observed for parks, recreation facilities, and street connectivity [41]. Others found that proximity to parks, recreation facilities and proximity to school [32,43,98,99] along with transport infrastructure were positively associated with physical activity in adolescents [99]. Traffic hazards (number of roads to cross, traffic speed) and local conditions (crime, area deprivation) were negatively associated with physical activity [44,99]. Obesogenic environmental attributes of homes, neighborhoods, and schools are believed to promote sedentary behavior among youth [100] and there is growing evidence that being socially connected with others contributes to adolescent wellbeing [46]. While some evidence exists to show the importance of the built environment for adolescent physical activity and well-being, the use of different methods and limited physical variability within any given environment may serve to consistently underestimate the associations observed. In this study, variance is maximised in two ways. Two major cities in New Zealand are sampled, and these data are subsequently combined with nine other countries through the IPEN-Adolescent study. The larger study will improve our understanding of the nature of the relationships that exist between adolescent physical activity, sedentary behavior and body weight with specific features of the built environment related to walkability, commuting and access to facilities for recreation.

Individuals (or at least parents) may self-select neighborhoods, therefore associations between built environment and walkability may in part be a reflection of neighborhood self-selection bias. Mixed results have been found when investigating neighborhood self-selection and walkability [101-105]. The relationship is a complex one and prospective studies are needed to study the effects of neighborhood self-selection on neighborhood walkability. When reviewing 38 empirical studies that used different approaches to explore the influence of self-selection, Cao and colleagues [106] established that all studies reviewed found a statistically significant influence of the built environment after accounting for self-selection. While exploring this particular relationship is not the focus of the present study, parents' neighborhood preference and self-selection will be accounted for in the analysis. As mentioned earlier, parents will be asked to rank the importance of a variety of reasons for choosing to reside in the particular neighbourhood. The reasons (that address self-selection) could be: easy access to services, walkable environment, and/or access to recreational and sporting facilities. This information will be used in the analysis.

When conducting spatial analyses on aggregated data, errors affecting the validity of results may be introduced [107]. The problem has been referred to as the Modifiable Areal Unit Problem defined as the 'geographic manifestation of the ecological fallacy in which conclusions based on data aggregated to a particular set of districts may change if one aggregates the same underlying data to a different set of districts' [108]. In other words, the way spatial data are aggregated may result in different findings. There has been disagreement in the literature on the best solution for this problem; however, it has been suggested that the only appropriate resolution is to use individual-level data that are geocoded based on residential location [109]. Indeed, our selection strategy uses geo-coded data and we are employing techniques (GPS and VERITAS) to gain a more accurate understanding of neighborhood boundaries for youth. This will substantially advance our knowledge in this field.

This study will contribute to national and international scientific knowledge by forming the NZ arm of the international IPEN-Adolescents collaboration, whereby adolescents' physical activity and sedentary behavior data are collected using a common methodology across multiple countries (Australia, Belgium, Brazil, China, Denmark, Malaysia, New Zealand, Portugal and USA). Furthermore the larger study will improve our understanding of the nature of the relationships that exist between adolescent physical activity, sedentary behavior and body weight with specific features of the built environment related to walkability, commuting and access to facilities for recreation.

Ultimately, by showing the relationships between health outcomes and the neighborhood built environment, we aim to influence and inform policy and city planning practices. City planners, policy makers and government agencies will be engaged early [110] [111]. Results will also be shared with other sustainable transport advocacy, urban planners, and public health organisations. Dissemination of findings to NZ secondary schools and students themselves will maximise the potential impact of the findings.

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Authors' contributions

EH developed the first draft of the manuscript. EH, SD, MO, SM, EC, HB, VI, JM, and GS contributed to the conception and the design of the study. All authors provided feedback during manuscript development. Each author has read and approved the final manuscript.

Competing interests

The authors declare that they have no competing interests.

References

1. Department of Health Physical Activity Health Improvement and Protection. At least five a week: Evidence on the impact of physical activity and its relationship to health. A report from the Chief Medical Officer. London: Department of Health, 2004.
2. Department of Health Physical Activity Health Improvement and Protection. Start Active, Stay Active: A report on physical activity for health from the four home countries' Chief Medical Officers. London: Department of Health, Physical Activity, Health Improvement and Protection, 2011.
3. Ministry of Health. DHB toolkit: Physical activity. Wellington: Ministry of Health, 2003.

4. U.S. Department of Health and Human Services. Physical Activity and Health: A Report of the Surgeon General. Atlanta, GA: Center for Disease Control and Prevention, 2002.
5. World Health Organization. Global recommendations on physical activity for health. Geneva: World Health Organization, 2010.
6. Janssen I, LeBlanc AG. Review Systematic review of the health benefits of physical activity and fitness in school-aged children and youth. *Int J Behav Nutr Phys Act* 2010;**7**:40.
7. Strong W, Malina R, Blimkie C, et al. Evidence based physical activity for school aged youth. *J Pediatr* 2005;**146**:732-37.
8. Brownson RC, Boehmer TK, Luke DA. Declining rates of physical activity in the United States: what are the contributors? *Annu Rev Public Health* 2005;**26**:421-43.
9. Dumith SC, Gigante DP, Domingues MR, et al. Physical activity change during adolescence: a systematic review and a pooled analysis. *Int J Epidemiol* 2011;**40**(3):685-98.
10. Matthews, Chen, Freedson, et al. Amount of time spent in sedentary behaviors in the United States, 2003–2004. *Am J Epidemiol* 2007;**167**(7):875-81 doi: 10.1093/aje/kwm390 published.
11. Mitchell J, Pate R, Beets M, et al. Time spent in sedentary behavior and changes in childhood BMI: a longitudinal study from ages 9 to 15 years. *Int J Obes* 2012;**37**(1):54-60.
12. Maddison R, Turley M, Legge N, et al. A National Survey of Children and Young People's Physical Activity and Dietary Behaviours in New Zealand: 2008/09. Auckland: Clinical Trials Research Unit, The University of Auckland, 2010.
13. Hamilton, Healy, Dunstan, et al. Too little exercise and too much sitting: Inactivity physiology and the need for new recommendations on sedentary behavior *Curr Cardiovasc Risk Rep* 2008;**2**(4):292-98 doi: 10.1007/s12170-008-0054-8published.
14. Hamilton M, Hamilton D, Zderic W. Exercise physiology versus inactivity physiology: an essential concept for understanding lipoprotein lipase regulation. *Exerc Sport Sci Rev* 2004;**32**:161-66.
15. Hamilton MT, Hamilton DG, Zderic TW. Role of low energy expenditure and sitting in obesity, metabolic syndrome, type 2 diabetes, and cardiovascular disease. *Diabetes* 2007;**56**(11):2655-67.
16. Telama R, Yang X, Viikari J, et al. Physical activity from childhood to adulthood: a 21-year tracking study. *Am J Prev Med* 2005;**28**(3):267-73.
17. Hancox RJ, Milne BJ, Poulton R. Association between child and adolescent television viewing and adult health: a longitudinal birth cohort study. *Lancet* 2004;**364**(9430):257-62.
18. Reilly JJ, McDowell ZC. Physical activity interventions in the prevention and treatment of paediatric obesity: systematic review and critical appraisal. *Proc Nutr Soc* 2003;**62**(3):611-20.
19. Dobbins M, De Corby K, Robeson P, et al.School-based physical activity programs for promoting physical activity and fitness in children and adolescents aged 6-18. *Cochrane Database of Systematic Reviews* 2009;**1**(1):1-106 doi: 10.1002/14651858.CD007651published.
20. Summerbell C, Waters E, Edmunds L, et al. Interventions for preventing obesity in children. *Cochrane Database Syst Rev* 2005;**3**(3):1-86.
21. King AC, Stokols D, Talen E, et al.Theoretical approaches to the promotion of physical activity: forging a transdisciplinary paradigm. *Am J Prev Med* 2002;**23**(2S):15-25.
22. Giles-Corti B, Timperio A, Bull F, et al. Understanding physical activity environmental correlates: increased specificity for ecological models. *Exerc Sport Sci Rev* 2005;**33**(4):175-81.
23. Hinckson EA, Garrett N, Duncan JS. Active commuting to school in New Zealand Children (2004-2008): A quantitative analysis. *Prev Med* 2011;**52**:332-36.
24. Witten K, Blakely T, Bagheri N, et al. Neighborhood built environment and transport and leisure physical activity: findings using objective exposure and outcome measures in New Zealand. *Environ Health Perspect* 2012;**120**(7):971–77.
25. Conn VS, Hafdahl AR, Mehr DR. Interventions to increase physical activity among healthy adults: meta-analysis of outcomes. *Am J Public Health* 2011;**101**(4):751-58.
26. Metcalf B, Henley W, Wilkin T. Effectiveness of intervention on physical activity of children: systematic review and meta-analysis of controlled trials with objectively measured outcomes (EarlyBird 54). *BMJ: British Medical Journal* 2012;**345**:1-11.
27. De Bourdeaudhuij I, Sallis JF, Saelens BE. Environmental correlates of physical activity in a sample of Belgian adults. *Am J Health Promot* 2003;**18**(1):83-92.

28. Sallis JF, Bowles HR, Bauman A, et al. Neighborhood environments and physical activity among adults in 11 countries. *Am J Prev Med* 2009;**36**(6):484-90.
29. Sallis JF, Glanz K. The role of built environments in physical activity, eating, and obesity in childhood. *The Future of Children* 2006;**16**(1):89-108.
30. Ding D, Sallis JF, Norman GJ, et al. Community food environment, home food environment, and fruit and vegetable intake of children and adolescents. *J Nutr Edu Behav* 2011;**44**(6):634–38.
31. Davison KK, Lawson CT. Do attributes in the physical environment influence children's physical activity? A review of the literature. *Int J Behav Nutr Phys Act* 2006;**3**(1):19.
32. Rodríguez DA, Cho G-H, Evenson KR, et al. Out and about: association of the built environment with physical activity behaviors of adolescent females. *Health & Place* 2012;**18**(1):55-62.
33. McDonald K, Hearst M, Farbakhsh K, et al. Adolescent physical activity and the built environment: a latent class analysis approach. *Health & Place* 2012;**18**(2):191-98.
34. Casey R, Chaix B, Weber C, et al. Spatial accessibility to physical activity facilities and to food outlets and overweight in French youth. *Int J Obes* 2012;**36**(7):914-19.
35. Yin L, Raja S, Li X, et al. Neighbourhood for playing: using GPS, GIS and accelerometry to delineate areas within which youth are physically active. *Urban Studies* 2013:1-18.
36. Laxer RE, Janssen I. The proportion of youths' physical inactivity attributable to neighbourhood built environment features. *Int J Health Geogr* 2013;**12**(1):31.
37. Lake A, Townshend T. Exploring the built environment, physical activity and related behaviours of young people attending school, college and those not in employment. *J Public Health* 2013;**35**(1):57-66.
38. Kasehagen L, Busacker A, Kane D, et al. Associations between neighborhood characteristics and physical activity among youth within rural–urban commuting areas in the US. *Matern Child Health J* 2012;**16**(2):258-67.
39. Hobin E, Leatherdale S, Manske S, et al. A multilevel examination of factors of the school environment and time spent in moderate to vigorous physical activity among a sample of secondary school students in grades 9–12 in Ontario, Canada. *Int J Public Health* 2012;**57**(4):699-709.
40. Badland HM, Schofield GM, Witten K, et al. Understanding the Relationship between Activity and Neighbourhoods(URBAN) Study: research design and methodology. *BMC Public Health* 2009;**9**(1):224.
41. Ding D, Sallis JF, Kerr J, et al. Neighborhood environment and physical activity among youth: a review. *Am J Prev Med* 2011;**41**(4):442-55.
42. Yin L, Raja S, Li X, et al. Neighbourhood for playing: using GPS, GIS and accelerometry to delineate areas within which youth are physically active. *Urban Studies* 2013.
43. Slater S, Fitzgibbon M, Floyd MF. Urban adolescents' perceptions of their neighborhood physical activity environments. *Leisure Sciences* 2013;**35**(2):167-83.
44. Kann L. Obesity and other correlates of physical activity and sedentary behaviors among US high school students. *J Obes* 2013;**2013** doi: http://dx.doi.org.ezproxy.aut.ac.nz/10.1155/2013/276318published.
45. Moore JB, Brinkley J, Crawford TW, et al. Association of the built environment with physical activity and adiposity in rural and urban youth. *Prev Med* 2012;**56** (2013):145–48.
46. Jose PE, Pryor J. New Zealand youth benefit from being connected to their family, school, peer group and community. *Youth Studies Australia* 2010;**29**(4):30-37.
47. Vandenbroucke JP, Von Elm E, Altman DG, et al. Strengthening the Reporting of Observational Studies in Epidemiology (STROBE): explanation and elaboration. *PLoS medicine* 2007;**4**(10):e297.
48. Statistics New Zealand. Subnational population estimates at 30 June 2012. Wellington: Statistics New Zealand, 2013.
49. Demographia. Demographia World Urban Areas: 9th Annual Edition (2013.03). Belleville, Illinois: Demographia, 2013.
50. Leslie E, Coffee N, Frank L, et al. Walkability of local communities: using geographic information systems to objectively assess relevant environmental attributes. *Health & Place* 2007;**13**(1):111-22.

51. Frank L, Kerr J, Chapman J, et al. Urban form relationships with walk trip frequency and distance among youth. *Am J Health Promot* 2007;**21**(4):S1-S7.
52. Frank LD, Sallis JF, Saelens BE, et al. The development of a walkability index: application to the Neighborhood Quality of Life Study. *Br J Sports Med* 2010;**44**(13):924-33.
53. Witten K, Pearce J, Day P. Neighbourhood Destination Accessibility Index: A GIS tool for measuring infrastructure support for neighbourhood physical activity. *Environment and Planning-Part A* 2011;**43**(1):205.
54. Sallis J, Kerr J, Conway J. TEAN (Teen Environment and Neighborhood) study (Unpublished). San Diego: Unversity of California San Diego, 2007-2011.
55. Kerr J, Sallis JF, Owen N, et al. Advancing science and policy through a coordinatediInternational study of physical activity and built environments: IPEN methods. *J Phys Act Health* 2012;**10**(4):581-601.
56. de Vries SI, Bakker I, Hopman-Rock M, et al. Clinimetric review of motion sensors in children and adolescents. *J Clin Epidemiol* 2006;**59**(7):670-80.
57. Trost SG, Pate RR, Freedson PS, et al. Using objective physical activity measures with youth: how many days of monitoring are needed? *Med Sci Sports Exerc* 2000;**32**(2):426-31.
58. Oliver M, Witten K, Kearns R, et al. Kids in the City Study: research design and methodology. *BMC public health* 2011;**11**(1):587.
59. Choi L, Liu Z, Matthews CE, et al.Validation of accelerometer wear and nonwear time classification algorithm. *Med Sci Sports Exerc* 2011;**43**(2):357-64.
60. Evenson KR, Catellier DJ, Gill K, et al. Calibration of two objective measures of physical activity for children. *J Sports Sci* 2008;**26**(14):1557-65.
61. Trost SG, Loprinzi PD, Moore R, et al. Comparison of accelerometer cut points for predicting activity intensity in youth. *Med Sci Sports Exerc* 2011;**43**(7):1360-68.
62. Cole T, Flegal KM, Nicholls D, et al. Body mass index cut offs to define thinness in children and adolescents: international survey. *BMJ* 2007;**335**(7612):194 doi: 10.1136/bmj.39238.399444published.
63. Inagami S, Cohen DA, Finch BK. Non-residential neighborhood exposures suppress neighborhood effects on self-rated health. *Soc Sci Med* 2007;**65**(8):1779-91.
64. Cummins S. Commentary: investigating neighbourhood effects on health—avoiding the 'local trap'. *Int J Epidemiol* 2007;**36**(2):355-57.
65. Kwan M-P. The uncertain geographic context problem. *Ann Assoc Am Geogr* 2012;**102**(5):958-68.
66. Chaix B, Méline J, Duncan S, et al. GPS tracking in neighborhood and health studies: A step forward for environmental exposure assessment, a step backward for causal inference? *Health & Place* 2013;**21**:46-51.
67. Golledge RG, Stimson RJ. Spatial Behavoir: A Geographical Perspective. New York: Guilford Press 1997.
68. Chaix B, Bean K, Leal C, et al. Individual/Neighborhood social factors and blood pressure in the RECORD cohort study which risk factors explain the associations? *Hypertension* 2010;**55**(3):769-75.
69. Chaix B, Billaudeau N, Thomas F, et al. Neighborhood effects on health: correcting bias from neighborhood effects on participation. *Epidemiology* 2011;**22**(1):18-26.
70. Chaix B, Kestens Y, Perchoux C, et al. An interactive mapping tool to assess individual mobility patterns in neighborhood studies. *Am J Prev Med* 2012;**43**(4):440-50.
71. Havard S, Reich BJ, Bean K, et al. Social inequalities in residential exposure to road traffic noise: an environmental justice analysis based on the RECORD Cohort Study. *Occup Environ Med* 2011;**68**(5):366-74.
72. Duncan S, Stewart TI, Oliver M, et al. Portable Global Positioning System receivers: Static validity and environmental conditions. *Am J Prev Med* 2013;**44**(22):e19-e29.
73. Kerr J, Duncan S, Schipperjin J. Using Global Positioning Systems in health research: a practical approach to data collection and processing. *Am J Prev Med* 2011;**41**(5):532-40.
74. Brownson RC, Hoehner CM, Day K, et al. Measuring the built environment for physical activity: State of the science. *Am J Prev Med* 2009;**36**(4):S99-S123. e12.

75. De Bourdeaudhuij I, Sallis JF, Saelens BE. Environmental correlates of physical activity in a sample of Belgian adults. *Am J Health Promot* 2003;**18**(1):83-92.
76. Leslie E, Saelens BE, Frank LD, et al. Residents' perceptions of walkability attributes in objectively different neighbourhoods: A pilot study. *Health & Place* 2005;**11**(3):227-36.
77. Saelens BE, Sallis JF, Black JB, et al.Neighbourhood-based differences in physical activity: An environment scale evaluation. *Am J Public Health* 2003;**93**(9):1552-58.
78. Cerin E, Conway TL, Cain KL, et al. Sharing good NEWS across the world: developing comparable scores across 12 countries for the neighborhood environment walkability scale (NEWS). *BMC Public Health* 2013;**13**(1):309.
79. Rosenberg D, Ding D, Sallis JF, et al. Neighborhood Environment Walkability Scale for Youth (NEWS-Y): reliability and relationship with physical activity. *Prev Med* 2009;**49**(2):213-18.
80. Van Der Horst K, Paw MJCA, Twisk JWR, et al. A brief review on correlates of physical activity and sedentariness in youth, 2007:1241.
81. Norman GJ, Schmid BA, Sallis JF, et al. Psychosocial and environmental correlates of adolescent sedentary behaviors. *Pediatrics* 2005;**116**(4):908.
82. Grow HM, Saelens BE, Kerr J, et al. Where are youth active? Roles of proximity, active transport, and built environment. *Med Sci Sports Exerc* 2008;**40**(12):2071.
83. Sallis J. The Active Where? Questionnaire. *http://www.drjamessallis.sdsu.edu/measures.html* 2005.
84. Frank L, Leerssen C, Chapman J, et al. Strategies for metropolitan Atlanta's regional transportation and air quality (SMARTRAQ). *Atlanta, GA: Georgia Institute of Technology* 2001.
85. Prochaska JJ, Sallis JF, Long B. A physical activity screening measure for use with adolescents in primary care. *Archives of Pediatrics & Adolescent Medicine* 2001;**155**(5):554-59.
86. Norman GJ, Sallis JF, Gaskins R. Comparability and reliability of paper-and computer-based measures of psychosocial constructs for adolescent physical activity and sedentary behaviors. *Res Q Exerc Sport* 2005;**76**(3):315-23.
87. Sallis JF, Nader PR, Broyles SL, et al. Correlates of physical activity at home in Mexican-American and Anglo-American preschool children. *Health Psychol* 1993;**12**(5):390-98.
88. Marshall S, Biddle S, Sallis J, et al. Clustering of sedentary behaviours and physical activity among youth: A cross-national study. *Pediatr Exerc Sci* 2002;**14**(410-417).
89. Duncan JS, Hopkins WG, Schofield G, et al. Effects of weather on pedometer-determined physical activity in children. *Med Sci Sports Exerc* 2008;**40**(8):1432.
90. Goldstein H, Browne W, Rasbash J. Multilevel modelling of medical data. *Stat Med* 2002;**21**(21):3291-315.
91. Burton P, Gurrin L, Sly P. Tutorial in biostatistics. Extending the simple linear regression model to account for correlated responses: an introduction to generalized estimating equations and multi-level mixed modeling. *Stat Med* 1998;**17**:1261-91.
92. Browne WJ, Draper D. A comparison of Bayesian and likelihood-based methods for fitting multilevel models. *Bayesian Analysis* 2006;**1**(3):473-514.
93. Austin PC. Estimating Multilevel Logistic Regression Models when the number of clusters is low: a comparison of different statistical software procedures. *Int J Biostats* 2010;**6**(1):1557-4679 doi: 10.2202/1557-4679.1195published.
94. Marrie RA, Dawson NV, Garland A. Quantile regression and restricted cubic splines are useful for exploring relationships between continuous variables. *J Clin Epidemiol* 2009;**62**(5):511-17. e1.
95. Attride-Stirling J. Thematic networks: an analytic tool for qualitative research. *Qual Res* 2001;**1**(3):385-405.
96. Östlund U, Kidd L, Wengström Y, et al. Combining qualitative and quantitative research within mixed method research designs: A methodological review. *Int J Nurs Stud* 2011;**48**(3):369.
97. Tashakkori A, Teddlie C. Handbook of mixed methods in social & behavioral research: Sage Publications, Inc, 2003.
98. Cohen DA, Ashwood S, Scott M, et al. Proximity to school and physical activity among middle school girls: the trial of activity for adolescent girls study. *Pediatrics* 2006;**118**(5):e1381.

99. Davison K, Lawson C. Do attributes in the physical environment influence children's physical activity? A review of the literature. *Int J Behav Nutr Phys Act* 2006;**3**(1):19.
100. Giles-Corti B, Kelty SF, Zubrick SR, et al. Encouraging walking for transport and physical activity in children and adolescents. *Sports Med* 2009;**39**(12):995-1009.
101. Owen N, Cerin E, Leslie E, et al. Neighborhood walkability and the walking behavior of Australian adults. *Am J Prev Med* 2007;**33**(5):387-95.
102. Boarnet MG, Sarmiento S. Can land-use policy really affect travel behaviour? A study of the link between non-work travel and land-use characteristics. *Urban Studies* 1998;**35**(7):1155-69.
103. Cao X, Handy SL, Mokhtarian PL. The influences of the built environment and residential self-selection on pedestrian behavior: evidence from Austin, TX. *Transportation* 2006;**33**(1):1-20.
104. Handy S, Cao X, Mokhtarian PL. Self-selection in the relationship between the built environment and walking: Empirical evidence from Northern California. *J Am Plann Assoc* 2006;**72**(1):55-74.
105. Frank LD, Saelens BE, Powell KE, et al. Stepping towards causation: do built environments or neighborhood and travel preferences explain physical activity, driving, and obesity? *Soc Sci Med* 2007;**65**(9):1898-914.
106. Cao X, Mokhtarian PL, Handy SL. Examining the impacts of residential self□selection on travel behaviour: a focus on empirical findings. *Transport Reviews* 2009;**29**(3):359-95.
107. Yang T-C. Modifiable areal unit problem. *GIS Resource Document* 2005.
108. Waller LA, Gotway CA. Applied spatial statistics for public health data: John Wiley & Sons, 2004.
109. Weeks JR. The role of spatial analysis in demographic research. *Spatially integrated social science* 2004:381-99.
110. McCann B. Making physical activity research relevant to policy makers. *J Phys Act Health* 2006;**3**(Supp1):S267-S72.
111. Brownson RC, Jones E. Bridging the gap: translating research into policy and practice. *Prev Med* 2009;**49**(4):313-15.

BUILT ENVIRONMENT AND PHYSICAL ACTIVITY IN NEW ZEALAND ADOLESCENTS: A PROTOCOL FOR A CROSS SECTIONAL STUDY

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Abstract

Introduction: Built-environment interventions have the potential to provide population-wide effects and provide the means for a sustained effect on behavior change. Population-wide effects for adult physical activity have been shown with selected built environment attributes; however, the association between the built environment and adolescent health behaviors is less clear. This New Zealand study is part of an international project across 10 countries (International Physical Activity and the Environment Network– Adolescents) that aims to characterize the links between built environment and adolescent health outcomes.

Methods and Analyses: An observational, cross-sectional study of the associations between measures of the built environment with physical activity, sedentary behavior, body size, and social connectedness in 1,600 New Zealand adolescents aged 12-18 years will be conducted in 2013-2014. Walkability and neighborhood destination accessibility indices will be objectively measured using Geographic Information Systems (GIS). Physical activity and sedentary behaviors will be objectively measured using accelerometers over seven consecutive days. Body mass index will be calculated as weight divided by squared height. Demographics, socioeconomic status, active commuting behaviors, and perceived neighborhood walkability will be assessed using the Neighborhood Environment Walkability Scale for Youth and psychosocial indicators. A web-based computer-assisted personal interview (CAPI) tool (VERITAS) and Global Positioning System (GPS) receivers will be used in a subsample of 300 participants. A qualitative research component will explore barriers and facilitators for physical activity in adolescents with respect to the built and social environment in a subsample of 80 participants.

Ethics and dissemination: The study received ethical approval from the Auckland University of Technology Ethics Committee (12/161). Data will be entered and stored into a secure (password protected) database. Only the named researchers will have access to the data. Data will be stored for 10 years and permanently destroyed thereafter. The results papers will be submitted for publication in peer-reviewed journals.

Strengths and limitations of this study

- Limited data exists on detailed and multilevel relationships of interaction between the social and physical environments specific to the NZ adolescents.
- The use of GPS/VERITAS will define the adolescents' geographical context and will provide accurate estimates of location in which physical activity takes place.
- The study forms the NZ arm of the international IPEN-Adolescents collaboration, whereby adolescents' physical activity and sedentary behavior data are collected using a common methodology across multiple countries.
- Parents may self-select neighborhoods, therefore associations between built environment and walkability may in part be a reflection of neighborhood self-selection bias. Parents' neighborhood preference and self-selection will be accounted for in the analysis.
- When conducting spatial analyses on aggregated data, errors affecting the validity of results may be introduced. Geo-coded data and other techniques will assist in gaining a more accurate understanding of neighborhood boundaries for adolescents.

Built environment and physical activity in New Zealand adolescents: A cross sectional study

Introduction

The benefits of physical activity in youth are well documented [1-5]. Regular moderate-to-vigorous physical activity (MVPA) is positively associated with musculoskeletal health, cardiovascular wellbeing (e.g., healthy blood pressure, lipid and lipoprotein levels, cardiovascular autonomic tone), metabolic health, maintenance of a healthy weight, psychological wellbeing (e.g., improved self-concept, reduced anxiety and depression), and reduced risk of type 2 diabetes [6,7]. The accumulation of at least 60 minutes of MVPA per day is recommended for youth; however, accumulating physical activity below this threshold is still beneficial, especially for those whose health is at risk (e.g., overweight or obese youth) [6]. Despite awareness of the well-established benefits of physical activity, rapid changes in technology and the habitual environment over the last 50 years may have caused an increase in sitting, passive travel, and subsequently a reduction in incidental physical activity [8]. Furthermore, over the course of adolescence, physical activity typically decreases by 60-70% [9], while sedentary behavior remains high at 7-14 hours per day [10-12]. The latter trend is particularly concerning given that emerging evidence suggests that sedentary behavior has negative effects on health that are independent of the beneficial effects of physical activity [13-15]. Additionally, levels of activity during school age years significantly predict activity levels [16] and health outcomes [17] into adulthood.

Behavioral modification programmes have only achieved limited and mostly short term physical activity improvements [18-20]. For sustainable changes that optimise positive behaviors, it is important to understand that physical activity and sedentary behaviors occur within a broader ecological framework [21]. It is recognised that in order to be effective, complex integrated interventions are required that include supportive policies and social and physical environments [22,23]. Manipulating social and physical environments to be more health promoting will likely have sustainable and far-reaching impacts on population health behaviors and outcomes. We have previously examined the relationship of objective built environment measures (i.e., destination access, street connectivity, dwelling density, land use mix) with accelerometer-derived and self-reported physical activity in adults [24]. The work was part of a larger international study (IPEN-International Physical activity and Environment Network) with 12 participating countries. The potential of walkable neighborhoods for supporting health-enhancing increases in physical activity, at least for adults, was high [24]. A one standard deviation increase in neighborhood walkability variables yielded a 7-13% increase in physical activity. This effect is likely to be much higher than effects achieved through behavioral intervention alone [25,26].

While the evidence base for associations between the built environment and physical activity in adults has been steadily accumulating [24,27,28], our understanding of this relationship in adolescents is at its infancy [29-38], and at times non-intuitive [33,39]. Adolescents were consistently identified in our adult focus groups in our previous study as a sub-group whose changing needs for independent mobility and age- and culturally-appropriate forms of physical activity are less likely to be met, particularly in more suburban built environment forms [40]. In a recent review, land-use mix and residential density were the most highly correlated built environment variables with overall physical activity in youth [41]. However,

the review did not find any environmental variables that consistently correlated with physical activity in adolescents. Nonetheless, latest research indicates that adolescents' physically activity tends to occur close to their homes [42,43], and that strong associations exist between inactivity with lower neighborhood walkability, amount of public open space, and neighborhood safety [44], as well as higher densities of cul-de-sac networks [36]. MVPA is significantly lower for rural adolescents compared to those living in urban environments, however these differences between neighborhood type are not seen for BMI [45]. Geospatial data indicate that adolescent girls engage in higher intensity physical activity in places with parks, schools, and higher population density, and accumulate lower levels of physical activity in places with more roads and food outlets [32]. Low-income adolescents were physically active at fields/courts, indoor recreation facilities, small and large parks, and swimming pools [43] but reduced accessibility of physical activity facilities and food outlets was associated with being overweight [34].

In the Built Environment and Adolescent New Zealanders (BEANZ) study, we seek to understand the relationship of physical activity, sedentary behavior, and body size with neighborhood-level built environment features in New Zealand (NZ) adolescents. We hypothesise that neighborhood walkability and neighborhood destination accessibility indices will be positively associated with minutes of MVPA, and inversely associated with minutes of sedentary time and body mass index (BMI). We will also investigate associations between the built environment and social connectedness to the community [46], the moderating effects of ethnicity and mediating effects of active commuting, neighborhood mobility, and perceived neighborhood walkability. A novel aspect of this study is the use of portable global positioning system (GPS) receivers together with web-based interactive mapping and geocoding software to examine adolescents' mobility and access to regular destinations. These ancillary data will enable the shape and scale of environmental exposure to be defined in considerable detail.

Our study forms part of the IPEN-Adolescent collaboration, using comparable data collection, management, and protocol sharing across 10 countries. By comparing diverse countries, built environmental heterogeneity can be captured (and therefore generate robust estimates of the real effects) while facilitating intra- and inter-country comparisons. The goal is to generate credible evidence to guide long-term town planning, policy change, and redesign of existing urban environments to maximise physical activity and community connectedness and minimise sedentary behavior and body size, all key determinants of human health.

Method and analysis

The standardized checklist for the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) recommendations was used to ensure that all elements recommended were address within this section [47].

Design

BEANZ will be based on an observational, cross-sectional design that examines the associations of objective and subjective measures of the built environment with physical activity, sedentary behavior, body size, and social connectedness in 1,600 NZ adolescents aged 12-18 years from eight secondary schools (approximately 200 participants per school). Moreover, differences between non-Māori and Māori population groups will be explored.

Demographics, socioeconomic status, active commuting, psychosocial indicators, and perceptions of the built environment will be measured in the full sample. Data will be collected in the 2013-2014 academic school years for the southern hemisphere. A GPS and interactive mapping sub-study of approximately 300 participants will assess neighborhood mobility by geolocating participants' destinations, modes of travel, activity locations, walking/cycling area, and perceived neighborhood boundaries. Focus groups will explore barriers and facilitators for physical activity with respect to neighborhood built and social environment in a subsample of approximately 80 participants. Data will be collected from two major cities in New Zealand: Auckland and Wellington. Auckland is the largest city in New Zealand with a population of approximately 1.4 million residents (one third of the country's population) [48], with a population density comparable to Los Angeles and Helsinki [49]. Wellington, the capital city of New Zealand, is located on the southern part of the North Island and has a population density comparable to Vancouver and Honolulu [49]. Ethical approval was received by the Institution's Ethics Committee (AUTEC, 12/161).

Neighborhood, school and participant selection

Associations between exposure and outcome variables are estimated based on data collected using a multistage sampling strategy. This strategy maximises heterogeneity in the exposure variables (built environment) while allowing comparisons to be made between those of low and high socioeconomic status (SES). In the first instance, GIS will be used to calculate three built environment measures – street connectivity, residential density, and land use mix –for each meshblock (smallest census tract units available in New Zealand) [40]. Street connectivity will be calculated by dividing the number of 3-or-more-way intersections by the area in square kilometres. To avoid edge effects associated with meshblocks delineated by street centrelines, street connectivity will be calculated for 20 m meshblock buffers. Intersections will be extracted from 2013 street network datasets provided by territorial authorities. Residential density will be calculated by dividing the number of dwellings by the residential land area. The number of dwellings will be obtained from the 2006 census data provided at the meshblock level. Residential land area will be derived from 2013 zoning datasets provided by territorial authorities. Land use mix will be calculated using the area of five land use categories (residential, commercial, industrial, open space, other) in an entropy equation [50]. Land uses will be determined using 2013 zoning datasets provided by territorial authorities. The raw scores for these three built environment measures will be normalised (converted to deciles) and summed to create a basic walkability index. This basic meshblock level walkability index will only be used in school and participant selection. The GIS-based built environment indices that will be created for each participant and used in analyses are described in a later section.

The raw scores for these built environment measures will be normalised and summed to create a basic walkability index. Next the basic walkability index and and pre-existing deprivation data (NZ Dep 2006) will be used to classify all Auckland and Wellington urban meshblocks) into one of four strata: (1) higher walkable, higher SES; (2) higher walkable, lower SES; (3) lower walkable, higher SES; and (4) lower walkable, lower SES. Meshblocks with the top four walkability/SES deciles are classified as higher walkable/SES, and meshblocks with the bottom four walkability/SES deciles are classified as lower walkable/SES. Meshblocks with walkability or SES in deciles 5 and 6 are excluded.

School selection will be based on convenience and close proximity to large numbers of meshblocks in each of the four strata. Within each school, all potential participants will be sampled, regardless of the quadrant they reside, and for each participant walkability will be calculated: all students will be assigned to the strata of the meshblock they primarily reside in. This procedure will take place prior to the consent process. Adolescents living in one of the four meshblock strata will be invited to participate in the study. Participation in the study will require written, informed consent from a parent or caregiver and written assent from the adolescent. At the time of consent parents will be asked to rate the importance of a variety of reasons for choosing to live in their neighbourhood. Subsequent schools will be selected on the basis of the quadrants that need to be balanced. In addition to this approach, care will be taken to balance student numbers across the four strata both within and across schools. A similar sampling strategy was used in our previous study of the environmental correlates of physical activity in adults; the heterogeneity generated by this technique permitted several meaningful associations to be detected [40]. A sub-sample of approximately 40 participants will be randomly selected from each school for the GPS and interactive mapping measurements.

Sample size

In adjusted multilevel models, it has been estimated that a sample of 1,600 adolescents recruited from two schools within each stratum (eight in total) would allow the detection of a small effect size (i.e., 1.4% of explained outcome variance found in similar studies conducted elsewhere [51]) with 80% power. The calculated sample size assumes a two-tailed probability level of 5%, a conservative clustering effect equivalent to an intra-class correlation coefficient of 0.10, and a regression model with 25 background covariates explaining 25% of the outcome variance (comparable to what might be expected from the selected variables). With an anticipated sample size of 320 Māori adolescents (our smallest sub-group comparison), the corresponding detectable effect size will be 7% of explained outcome variance (medium effect size).

Exposure, outcomes and covariates

Exposures

GIS data provide multiple spatially-referenced layers that can be used to create meaningful and objective exposure measures of the built environment. They are used to objectively characterise the built environment surrounding the primary home address of each participant and can be applied across a range of road network buffers (e.g., 500 m, 800 m, 1000 m, and 1600 m) in order to evaluate differences between various limits of exposure. Road network buffers can be created to define areas that can be reached on the street network system, but exclude areas that are not accessible due to major barriers (motorway, river, lake). Two main indices, each a composite function of 2-8 other variables, are used to assess physical environmental features: walkability index [52] and neighborhood destination accessibility index [53]. These are described in more detail below. All exposure measures (Table 1) follow the common protocols established for the international IPEN-Adolescents collaboration.

Table 1. Summary of study exposure, outcomes, and covariate

Exposure	**Covariates**
Detailed walkability index	Demographics
- Net residential density	- Age
- Land use mix	- Sex
- Retail density	- Ethnicity
- Street connectivity	- School

- Street discontinuity	Socioeconomic status
Neighborhood destination accessibility index	- Parent education
- Education destinations	- Parent occupation
- Transport destinations	- Family car ownership
- Recreation destinations	- Household crowding
- Social and cultural destinations	Active commuting
- Food retail destinations	- Frequency of active commuting
- Financial destinations	- Duration of active commuting
- Health destinations	Neighborhood mobility
- Other retail	- Frequency and location of regular destinations
Outcomes	- Frequency and location of activity
Physical activity behavior	- Total walking area
- Minutes of MVPA	- Total cycling area
- Minutes of light activity	- Perceived neighborhood boundary
Sedentary behavior	Perceived neighborhood walkability
- Minutes of overall sedentary activity	- Perceived residential density
- Minutes of television watching	- Perceived land use mix
Body size	- Perceived traffic/crime safety
- Body mass index	- Perceived aesthetics
- Waist circumference	Psychosocial indicators
	- Self-efficacy
	- Cons/barriers
	- Family support
	- Peer support
	Weather
	- Total rainfall
	- Mean temperature
	- Hours of daylight

Detailed walkability

The detailed walkability index is a summary score of five distinct variables calculated within GIS: net residential density, land use mix, retail density, street connectivity, and street discontinuity. This protocol was created for the US-based Neighborhood Quality of Life Study project, [52] and has been subsequently implemented in the US-based TEAN study [54], the Australian PLACE study, [50] and all IPEN Adult country study sites [55].

Neighborhood Destination Accessibility

Pedestrian access to destinations will be calculated using the Neighborhood Destination Accessibility Index (NDAI) [53]. The NDAI is an objective measure of pedestrian access to neighborhood destinations; it characterises the distribution of urban infrastructure within an 800m street network distance from residence. The NDAI has an advantage over most previous area-level measures of the urban environment in that it captures the range and intensity of everyday destinations such as schools, supermarkets and cafes, which may encourage active travel and enhance recreational physical activity at the population level. As well, the NDAI has been specifically designed for the New Zealand environment. The eight domains captured in the NDAI are education, transport, recreation and play, social and cultural, food retail, financial, health, and other retail.

Outcomes

Physical Activity

Minutes of MVPA will be objectively measured using hip-mounted triaxial accelerometers (Actigraph GT3X+) over seven consecutive days. The GT3X+ is a small, durable, and water resistant device worn on an elastic belt that records the frequency, duration, and intensity of physical activity with a high level of accuracy and precision [56]. Participants are asked to wear the Actigraph during all waking hours (except when bathing or swimming) for seven days; however, at least five complete days (including at least one weekend day) will be required for analysis to ensure reliable estimates of MVPA [57]. Consistent with previous research, a valid day will be defined as at least 10 hours of data for weekdays and 8 hours for weekend days; non-wear time will be defined as 60 minutes of consecutive zero counts [58,59]. In addition, each participant will be given a seven-day compliance log to complete daily, which assists with identifying non-wear periods. Upon collection of the accelerometer, data are downloaded and screened for completeness and possible malfunction using the Meterplus software (www.meterplussoftware.com). Accelerometer count data will be classified into minutes of light, moderate, and vigorous activity using thresholds developed by Evenson and colleagues [60]; these have performed well in a recent comparison of accelerometer count thresholds for youth [61].

Sedentary Behavior

Minutes of sedentary activity will be objectively assessed using the GT3X+ accelerometer over the seven-day measurement period. The aforementioned cut-points established by Evenson and colleagues [60] will be used to define sedentary time (< 100 counts per minute).

Body Size

Height, weight, and waist circumference of each participant will be measured by trained field researchers using a stadiometer, calibrated scales, and a tape measure. These procedures occur immediately before the researchers distribute the accelerometers; participants wear light clothing and shoes are removed. BMI will be calculated as weight divided by squared height. Participants are classified into weight status categories using age- and sex-specific BMI thresholds [62].

Covariates

Demographics and socioeconomic status

Age, sex, ethnicity, and SES will be collected from the participants. Consistent with the IPEN-adolescents protocol, household income will be the preferred SES indicator, but highest level of parental education will be used when income is unavailable.

Active commuting

The frequency, distance, duration, and mode of all active commuting trips to or from the home address in the previous six months will be assessed with the CAPI. The recall of each trip will be aided by a basic travel log (time, location, and mode of transport only) to be completed nightly with the accelerometer compliance log. Participants will be asked to bring this information with them to the subsequent CAPI.

Neighborhood Mobility

The majority of studies investigating the built environment and health have focused exclusively on residential neighborhoods as a predictor of exposure [63,64], and overlooked the prospect that a large proportion of activity choices may be influenced by additional environments that are experienced during daily routines. This may reduce the accuracy of environmental exposure assessment [65] and introduce errors that may confound research results. It has been suggested that investigating aspects of daily mobility (regular destinations and the movement between them) will be important to enhance the assessment of exposure [66] and resolve the Uncertain Geographic Context Problem [67]. Using GPS and interactive activity destination questionnaires, we aim to accurately capture the full extent of daily mobility, and its mediating built environment effect on health.

The Visualization and Evaluation of Route Itineraries, Travel Destinations, and Activity Spaces (VERITAS) is a web-based CAPI tool integrating interactive mapping capacities (based on Google Maps) and has the potential to explore destinations both inside and outside the residential neighborhood. VERITAS was initially developed and tested for the RECORD Cohort Study, a major longitudinal study of over 7,200 French adults [68-71]. The applicability and feasibility of this method to an adolescent population is detailed elsewhere (manuscript under review but available on request). While we will be using GIS to provide an objective assessment of the surrounding environment (i.e., exposure measures), VERITAS will allow the research team to search and geolocate participants' regular destinations (visited within the previous 6 months), activity locations, walking/cycling area, routes and modes of travel between locations, travel companions, and perceived or experienced neighborhood boundaries (i.e., neighborhood mobility). The VERITAS programme will run through an internet browser on a laptop computer, and will be designed to automatically upload all participant responses to our secure database when connected to a wireless network. Spatio-temporal data will be collected using the Qstarz BT-Q1000XT GPS receiver (Qstarz International, Taipai, Taiwan) which has been deemed one of the more accurate portable GPS receivers on the market [72]. The GPS will be worn in a pouch alongside the accelerometer. GPS data will be cleaned, filtered and merged with accelerometer data using the Personal Activity Location Measurement System (PALMS, refer to: https://ucsd-palms-project.wikispaces.com) [73]. The merged data streams retrieved from PALMS will be disaggregated into discrete trips and imported into ArcGIS for further analysis. Data obtained from GPS and VERITAS differ both temporally (previous 1 week and 6 months, respectively) and spatially (a continuous sequential polyline compared with point data). Although VERITAS will be able to obtain data for extended periods, it lacks the temporal sequence of events available from GPS tracking. However, as short periods of GPS monitoring may not truly represent destinations visited over extended periods, the combination of both has been recommended to create complementary and more robust measures of environmental exposure [70].

The neighborhood mobility data will allow the demarcation of the territorial range by active travel modes. A spatial 'polygon' will be created consisting of a multisided geometric shape surrounding the home address that connects the various locations to which participants claim to have walked or cycled. The area (m^2) within these polygons will be calculated and used to define separate shapes based on the travel modes. In situations where participants walk or cycle to only one location (e.g., school) the polygon area will be the distance between the location and home addresses multiplied by 1 m. As with the active commuting assessment, the recall of visited locations and trips will be aided by the travel log that will be completed daily. Finally, using VERITAS, each participant will be able to map their perceived neighborhood boundary, allowing us to isolate the effects of their self-defined neighborhood environment on the outcome measures.

Perceived Neighborhood Walkability

In order to understand the mediating effect of individual perceptions of the neighborhood on the relationship between the objectively-measured built environment and physical activity behavior, the Neighborhood Environment Walkability Scale for Youth (NEWS-Y) [81] will be administered as a self-completion hard copy survey. NEWS-Y is based on the NEWS, which has demonstrated good reliability and validity [74-78]. In addition to the GIS-based walkability index variables (residential density, land use mix, street connectivity), NEWS-Y assesses pedestrian/cycle facilities, aesthetics, traffic safety, and crime safety. The ten NEWS-Y subscales have acceptable test-retest reliability (ICC: 0.56-0.87) and specific subscales were correlated significantly with physical activity for adolescents [79].

Psychosocial Indicators

A small number of psychosocial variables associated with adolescent physical activity will be measured in the study. These include: self-efficacy; perceived barriers to being physically activity; family support; and peer support [79]. These variables have shown the most consistent psychosocial correlations with adolescent physical activity in the literature [80]. Further, by including such items we are able to examine our findings within a multilevel framework thereby accounting for and separating the various layers of influence (i.e., individual, social, and physical environments) [81].

Self-reported physical activity, sedentary behavior and commuting to school

In addition to perceived neighbourhood walkability and psychosocial indicators, participants will be asked to report on commuting (to and from school, walking and biking, barriers to walking and cycling) [82-84], physical activity (at and outside of school, places for, barriers in the neighbourhood, decisions about, confidence about, enjoyment of, social support, workout equipment, activity rules, and athletic ability) [85-87], and sedentary behavior (during school and weekend days, things in the bedroom and personal electronics) [88]. The scales have shown to be reliable and valid in the adolescent population [82-84,88].

Weather

We have previously demonstrated the significant impact of inclement weather conditions on physical activity in New Zealand children [89]. To monitor these potential confounding effects we will obtain hourly rainfall, mean temperature, and hours of daylight statistics from the New Zealand Met Service for each data collection day and use these as covariates in the models.

Procedures

Data will be collected from participants within the school setting in school hours. During the measurement session, the NEWS-Y [79] questionnaire will be administered, anthropometric measures will be taken and accelerometers and compliance logs will be distributed. Text messages will be sent to adolescents/parents before data collection session as a reminder to attend. A random sub-sample of 40 adolescents per school will be allocated a GPS receiver to wear in conjunction with the accelerometer, and will complete the VERITAS interview. All participants will be instructed on the correct use, wear-time, and care of the equipment. Participants will be issued with a $20 shopping voucher upon completion of data collection and return of the monitors and compliance logs.

Quantitative Analyses

The proposed dataset will have a hierarchical independent variable structure which consists of person-level observations nested within neighborhoods and schools. The main aim of the study is to examine confounder-adjusted associations of environmental variables with physical activity and body size outcomes. For this purpose, cross-classified (by neighborhoods and schools) generalized linear mixed models (MGLM) with random intercepts will be used. These can account for multiple sources of dependency (schools and neighborhoods) and different types of data (e.g., continuous or binary) following a Normal or other types of distributions (e.g., negative binomial, Poisson) [90]. MGLMs perform well when the number of observations across areas is highly unbalanced, [91] which will be relevant to this project as the number of participants may vary substantially across schools and neighborhoods. Given the relatively small number of strata included in the study, MGLMs will be estimated using Restricted Maximum Likelihood (REML) or Bayesian Markov chain Monte Carlo (MCMC) methods with non-informative priors, [92] the latter appropriate for binary (e.g., overweight/obese vs. normal weight) [92,93] or non-normally distributed outcomes [90]. Non-linear relationship will be examined using restricted cubic splines [94]. A probability level of 0.05 will be adopted.

Qualitative Methodology

A total of 16 focus groups, with approximately 5-8 participants, will be conducted at eight participating schools. One researcher (VI) will conduct all the focus groups and at least one of the co-researchers will assist. Variability in walkability will be sought by recruiting two schools in Auckland (representing relatively low walkability) and Wellington (relatively high walkability). However students within focus groups will be selected to represent a range of neighborhood settings to facilitate discussion on differing experiences of the built environment. Participants will also take part in the quantitative component and completed all data collection. To aid open discussion and allow meaningful comparisons separate focus groups will be conducted by age, with younger students (approximately 12-14 years) further stratified by sex, and older students (approximately 15-18 years) in mixed sex groups [43]. Focus groups will be conducted using 40 min school periods to accommodate school timetables semi-structured interview. The focus groups are designed to examine the enablers and barriers to being physically active, particularly with regard to active transport, engagement in formal and informal physical activity, safety, and social drivers. Researchers will specifically seek discussion on activity within participants' residential neighborhood and school environments as well as alternative activity spaces in their everyday lives, including those outside of their geographical suburbs. Maps of local environments to prompt discussion on where youth are active (and where they avoid), types of activity, and travel routes will be used. Interviews will be digitally recorded and transcribed by group, with all individual identifying information removed.

Qualitative Analyses

Initially, two of the researchers will independently read the transcripts, code and extract themes. The themes will be presented to the team. Disagreement will be resolved through discussion and themes will be confirmed. A coding framework will be developed using NVivo software to organise data generated by the project research questions (deductive) and emergent topics (inductive) [95]. Analyses will be conducted across and within groups to examine commonalities and differences by built environment settings and individual factors (i.e., sex, age, and culture). Concurrent analyses of qualitative and quantitative data will allow insightful integration and triangulation of findings across the study components, allowing us to draw inferences about how youth interact with and manage their lived environments, and what that means for their physical activity and wellbeing [96,97].

Ethics and dissemination

All adolescents will be required to provide assent to participate in the study. An information sheet will be designed specifically for adolescents in a manner that it will be easy to understand. Additionally, all parents of the assenting adolescents will be required to provide parental consent. Parents will also receive a detailed information sheet outlining the study and its requirements.

Data will be entered and stored into a secure (password protected) database. Only the named researchers will have access to the data. Data will be stored for 10 years and permanently destroyed thereafter.

It is unlikely that participants will experience discomfort or embarrassment during data collection. However, as body measures of weight and height will be objectively assessed, there is the potential of concern around body weight and size. The institution's counselling services will be accessed if a situation arises. All body measurements will be taken behind a portable screen with gender appropriate research officers. All data will be kept private and confidential.

At the completion of the study, results will be provided to key stakeholders and organisations (e.g., high schools, adolescents, and parents). Results will be disseminated by means of a written report to schools that have participated in the study. Adolescents and/or their parents/legal guardians will receive a report detailing the individual results collected. Government organizations, health boards, and councils, will be able to access key findings and recommendations resulting from the project through seminar presentations and report distribution. Research findings will also be circulated to the scientific community in the form publications in refereed journals.

Discussion

We have described the methods for the BEANZ study which seeks to estimate strengths of association between objective measures of the local environment with accelerometer-derived and self-reported physical activity and sedentary behavior in youth. A novel aspect of this study is the exploration of detailed and multilevel relationships of interaction between the social and physical environments specific to the NZ adolescents. This will be achieved through additional measures (e.g., GPS, VERITAS, focus groups, NDAI) which collectively serve to advance knowledge in this important area of health research, policy advocacy, and ultimately youth health outcomes. Particularly, the use of GPS/VERITAS to identify the locations that adolescents visit on a daily basis, defining their geographical context, will provide us with accurate estimates of location in which physical activity takes place.

International evidence shows that the most consistent environmental attributes positively associated with reported physical activity in youth were land use mix and residential density, but inconsistent findings have been observed for parks, recreation facilities, and street connectivity [41]. Others found that proximity to parks, recreation facilities and proximity to school [32,43,98,99] along with transport infrastructure were positively associated with physical activity in adolescents [99]. Traffic hazards (number of roads to cross, traffic speed) and local conditions (crime, area deprivation) were negatively associated with physical activity [44,99]. Obesogenic environmental attributes of homes, neighborhoods, and schools are believed to promote sedentary behavior among youth [100] and there is growing evidence that being socially connected with others contributes to adolescent wellbeing [46]. While some evidence exists to show the importance of the built environment for adolescent physical activity and well-being, the use of different methods and limited physical variability within any given environment may serve to consistently underestimate the associations observed. In this study, variance is maximised in two ways. Two major cities in New Zealand are sampled, and these data are subsequently combined with nine other countries through the IPEN-Adolescent study. The larger study will improve our understanding of the nature of the relationships that exist between adolescent physical activity, sedentary behavior and body weight with specific features of the built environment related to walkability, commuting and access to facilities for recreation.

Individuals (or at least parents) may self-select neighborhoods, therefore associations between built environment and walkability may in part be a reflection of neighborhood self-selection bias. Mixed results have been found when investigating neighborhood self-selection and walkability [101-105]. The relationship is a complex one and prospective studies are needed to study the effects of neighborhood self-selection on neighborhood walkability. When reviewing 38 empirical studies that used different approaches to explore the influence of self-selection, Cao and colleagues [106] established that all studies reviewed found a statistically significant influence of the built environment after accounting for self-selection. While exploring this particular relationship is not the focus of the present study, parents' neighborhood preference and self-selection will be accounted for in the analysis. As mentioned earlier, parents will be asked to rank the importance of a variety of reasons for choosing to reside in the particular neighbourhood. The reasons (that address self-selection) could be: easy access to services, walkable environment, and/or access to recreational and sporting facilities. This information will be used in the analysis.

When conducting spatial analyses on aggregated data, errors affecting the validity of results may be introduced [107]. The problem has been referred to as the Modifiable Areal Unit Problem defined as the 'geographic manifestation of the ecological fallacy in which conclusions based on data aggregated to a particular set of districts may change if one aggregates the same underlying data to a different set of districts' [108]. In other words, the way spatial data are aggregated may result in different findings. There has been disagreement in the literature on the best solution for this problem; however, it has been suggested that the only appropriate resolution is to use individual-level data that are geocoded based on residential location [109]. Indeed, our selection strategy uses geo-coded data and we are employing techniques (GPS and VERITAS) to gain a more accurate understanding of neighborhood boundaries for youth. This will substantially advance our knowledge in this field.

This study will contribute to national and international scientific knowledge by forming the NZ arm of the international IPEN-Adolescents collaboration, whereby adolescents' physical activity and sedentary behavior data are collected using a common methodology across multiple countries (Australia, Belgium, Brazil, China, Denmark, Malaysia, New Zealand, Portugal and USA). Furthermore the larger study will improve our understanding of the nature of the relationships that exist between adolescent physical activity, sedentary behavior and body weight with specific features of the built environment related to walkability, commuting and access to facilities for recreation.

Ultimately, by showing the relationships between health outcomes and the neighborhood built environment, we aim to influence and inform policy and city planning practices. City planners, policy makers and government agencies will be engaged early [110] [111]. Results will also be shared with other sustainable transport advocacy, urban planners, and public health organisations. Dissemination of findings to NZ secondary schools and students themselves will maximise the potential impact of the findings.

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Authors' contributions

EH developed the first draft of the manuscript. EH, SD, MO, SM, EC, HB, VI, JM, and GS contributed to the conception and the design of the study. All authors provided feedback during manuscript development. Each author has read and approved the final manuscript.

Competing interests

The authors declare that they have no competing interests.

References

1. Department of Health Physical Activity Health Improvement and Protection. At least five a week: Evidence on the impact of physical activity and its relationship to health. A report from the Chief Medical Officer. London: Department of Health, 2004.
2. Department of Health Physical Activity Health Improvement and Protection. Start Active, Stay Active: A report on physical activity for health from the four home countries' Chief Medical Officers. London: Department of Health, Physical Activity, Health Improvement and Protection, 2011.
3. Ministry of Health. DHB toolkit: Physical activity. Wellington: Ministry of Health, 2003.

4. U.S. Department of Health and Human Services. Physical Activity and Health: A Report of the Surgeon General. Atlanta, GA: Center for Disease Control and Prevention, 2002.
5. World Health Organization. Global recommendations on physical activity for health. Geneva: World Health Organization, 2010.
6. Janssen I, LeBlanc AG. Review Systematic review of the health benefits of physical activity and fitness in school-aged children and youth. *Int J Behav Nutr Phys Act* 2010;**7**:40.
7. Strong W, Malina R, Blimkie C, et al. Evidence based physical activity for school aged youth. *J Pediatr* 2005;**146**:732-37.
8. Brownson RC, Boehmer TK, Luke DA. Declining rates of physical activity in the United States: what are the contributors? *Annu Rev Public Health* 2005;**26**:421-43.
9. Dumith SC, Gigante DP, Domingues MR, Kohl HW. Physical activity change during adolescence: a systematic review and a pooled analysis. *Int J Epidemiol* 2011;**40**(3):685-98.
10. Matthews, Chen, Freedson, et al. Amount of time spent in sedentary behaviors in the United States, 2003–2004. *Am J Epidemiol* 2007;**167**(7):875-81 doi: 10.1093/aje/kwm390 published.
11. Mitchell J, Pate R, Beets M, Nader P. Time spent in sedentary behavior and changes in childhood BMI: a longitudinal study from ages 9 to 15 years. *Int J Obes* 2012;**37**(1):54-60.
12. Maddison R, Turley M, Legge N, Mitchelhill G. A National Survey of Children and Young People's Physical Activity and Dietary Behaviours in New Zealand: 2008/09. Auckland: Clinical Trials Research Unit, The University of Auckland, 2010.
13. Hamilton, Healy, Dunstan, Zedric, Owen. Too little exercise and too much sitting: Inactivity physiology and the need for new recommendations on sedentary behavior *Curr Cardiovasc Risk Rep* 2008;**2**(4):292-98 doi: 10.1007/s12170-008-0054-8published.
14. Hamilton M, Hamilton D, Zderic W. Exercise physiology versus inactivity physiology: an essential concept for understanding lipoprotein lipase regulation. *Exerc Sport Sci Rev* 2004;**32**:161-66.
15. Hamilton MT, Hamilton DG, Zderic TW. Role of low energy expenditure and sitting in obesity, metabolic syndrome, type 2 diabetes, and cardiovascular disease. *Diabetes* 2007;**56**(11):2655-67.
16. Telama R, Yang X, Viikari J, Välimäki I, Wanne O, Raitakari O. Physical activity from childhood to adulthood: a 21-year tracking study. *Am J Prev Med* 2005;**28**(3):267-73.
17. Hancox RJ, Milne BJ, Poulton R. Association between child and adolescent television viewing and adult health: a longitudinal birth cohort study. *Lancet* 2004;**364**(9430):257-62.
18. Reilly JJ, McDowell ZC. Physical activity interventions in the prevention and treatment of paediatric obesity: systematic review and critical appraisal. *Proc Nutr Soc* 2003;**62**(3):611-20.
19. Dobbins M, De Corby K, Robeson P, Husson H, Tirilis D. School-based physical activity programs for promoting physical activity and fitness in children and adolescents aged 6-18. *Cochrane Database of Systematic Reviews* 2009;**1**(1):1-106 doi: 10.1002/14651858.CD007651published.
20. Summerbell C, Waters E, Edmunds L, Kelly S, Brown T, Campbell K. Interventions for preventing obesity in children. *Cochrane Database Syst Rev* 2005;**3**(3):1-86.
21. King AC, Stokols D, Talen E, Brassington GS, Killingsworth R. Theoretical approaches to the promotion of physical activity: forging a transdisciplinary paradigm. *Am J Prev Med* 2002;**23**(2S):15-25.
22. Giles-Corti B, Timperio A, Bull F, Pikora T. Understanding physical activity environmental correlates: increased specificity for ecological models. *Exerc Sport Sci Rev* 2005;**33**(4):175-81.
23. Hinckson EA, Garrett N, Duncan JS. Active commuting to school in New Zealand Children (2004-2008): A quantitative analysis. *Prev Med* 2011;**52**:332-36.
24. Witten K, Blakely T, Bagheri N, et al. Neighborhood built environment and transport and leisure physical activity: findings using objective exposure and outcome measures in New Zealand. *Environ Health Perspect* 2012;**120**(7):971–77.
25. Conn VS, Hafdahl AR, Mehr DR. Interventions to increase physical activity among healthy adults: meta-analysis of outcomes. *Am J Public Health* 2011;**101**(4):751-58.
26. Metcalf B, Henley W, Wilkin T. Effectiveness of intervention on physical activity of children: systematic review and meta-analysis of controlled trials with objectively measured outcomes (EarlyBird 54). *BMJ: British Medical Journal* 2012;**345**:1-11.

27. De Bourdeaudhuij I, Sallis JF, Saelens BE. Environmental correlates of physical activity in a sample of Belgian adults. *Am J Health Promot* 2003;**18**(1):83-92.
28. Sallis JF, Bowles HR, Bauman A, et al. Neighborhood environments and physical activity among adults in 11 countries. *Am J Prev Med* 2009;**36**(6):484-90.
29. Sallis JF, Glanz K. The role of built environments in physical activity, eating, and obesity in childhood. *The Future of Children* 2006;**16**(1):89-108.
30. Ding D, Sallis JF, Norman GJ, et al. Community food environment, home food environment, and fruit and vegetable intake of children and adolescents. *J Nutr Edu Behav* 2011;**44**(6):634–38.
31. Davison KK, Lawson CT. Do attributes in the physical environment influence children's physical activity? A review of the literature. *Int J Behav Nutr Phys Act* 2006;**3**(1):19.
32. Rodríguez DA, Cho G-H, Evenson KR, et al. Out and about: association of the built environment with physical activity behaviors of adolescent females. *Health & Place* 2012;**18**(1):55-62.
33. McDonald K, Hearst M, Farbakhsh K, et al. Adolescent physical activity and the built environment: a latent class analysis approach. *Health & Place* 2012;**18**(2):191-98.
34. Casey R, Chaix B, Weber C, et al. Spatial accessibility to physical activity facilities and to food outlets and overweight in French youth. *Int J Obes* 2012;**36**(7):914-19.
35. Yin L, Raja S, Li X, Lai Y, Epstein L, Roemmich J. Neighbourhood for playing: using GPS, GIS and accelerometry to delineate areas within which youth are physically active. *Urban Studies* 2013:1-18.
36. Laxer RE, Janssen I. The proportion of youths' physical inactivity attributable to neighbourhood built environment features. *Int J Health Geogr* 2013;**12**(1):31.
37. Lake A, Townshend T. Exploring the built environment, physical activity and related behaviours of young people attending school, college and those not in employment. *J Public Health* 2013;**35**(1):57-66.
38. Kasehagen L, Busacker A, Kane D, Rohan A. Associations between neighborhood characteristics and physical activity among youth within rural–urban commuting areas in the US. *Matern Child Health J* 2012;**16**(2):258-67.
39. Hobin E, Leatherdale S, Manske S, Dubin J, Elliott S, Veugelers P. A multilevel examination of factors of the school environment and time spent in moderate to vigorous physical activity among a sample of secondary school students in grades 9–12 in Ontario, Canada. *Int J Public Health* 2012;**57**(4):699-709.
40. Badland HM, Schofield GM, Witten K, et al. Understanding the Relationship between Activity and Neighbourhoods(URBAN) Study: research design and methodology. *BMC Public Health* 2009;**9**(1):224.
41. Ding D, Sallis JF, Kerr J, Lee S, Rosenberg DE. Neighborhood environment and physical activity among youth: a review. *Am J Prev Med* 2011;**41**(4):442-55.
42. Yin L, Raja S, Li X, Lai Y, Epstein L, Roemmich J. Neighbourhood for playing: using GPS, GIS and accelerometry to delineate areas within which youth are physically active. *Urban Studies* 2013.
43. Slater S, Fitzgibbon M, Floyd MF. Urban adolescents' perceptions of their neighborhood physical activity environments. *Leisure Sciences* 2013;**35**(2):167-83.
44. Kann L. Obesity and other correlates of physical activity and sedentary behaviors among US high school students. *J Obes* 2013;**2013** doi: http://dx.doi.org.ezproxy.aut.ac.nz/10.1155/2013/276318published.
45. Moore JB, Brinkley J, Crawford TW, Evenson KR, Brownson RC. Association of the built environment with physical activity and adiposity in rural and urban youth. *Prev Med* 2012;**56** (2013):145–48.
46. Jose PE, Pryor J. New Zealand youth benefit from being connected to their family, school, peer group and community. *Youth Studies Australia* 2010;**29**(4):30-37.
47. Vandenbroucke JP, Von Elm E, Altman DG, et al. Strengthening the Reporting of Observational Studies in Epidemiology (STROBE): explanation and elaboration. *PLoS medicine* 2007;**4**(10):e297.
48. Statistics New Zealand. Subnational population estimates at 30 June 2012. Wellington: Statistics New Zealand, 2013.

49. Demographia. Demographia World Urban Areas: 9th Annual Edition (2013.03). Belleville, Illinois: Demographia, 2013.
50. Leslie E, Coffee N, Frank L, Owen N, Bauman A, Hugo G. Walkability of local communities: using geographic information systems to objectively assess relevant environmental attributes. *Health & Place* 2007;**13**(1):111-22.
51. Frank L, Kerr J, Chapman J, Sallis J. Urban form relationships with walk trip frequency and distance among youth. *Am J Health Promot* 2007;**21**(4):S1-S7.
52. Frank LD, Sallis JF, Saelens BE, et al. The development of a walkability index: application to the Neighborhood Quality of Life Study. *Br J Sports Med* 2010;**44**(13):924-33.
53. Witten K, Pearce J, Day P. Neighbourhood Destination Accessibility Index: A GIS tool for measuring infrastructure support for neighbourhood physical activity. *Environment and Planning-Part A* 2011;**43**(1):205.
54. Sallis J, Kerr J, Conway J. TEAN (Teen Environment and Neighborhood) study (Unpublished). San Diego: Unversity of California San Diego, 2007-2011.
55. Kerr J, Sallis JF, Owen N, De Bourdeaudhuij I, Cerin E, Reis R. Advancing science and policy through a coordinatediInternational study of physical activity and built environments: IPEN methods. *J Phys Act Health* 2012;**10**(4):581-601.
56. de Vries SI, Bakker I, Hopman-Rock M, Hirasing RA, van Mechelen W. Clinimetric review of motion sensors in children and adolescents. *J Clin Epidemiol* 2006;**59**(7):670-80.
57. Trost SG, Pate RR, Freedson PS, Sallis JF, Taylor WC. Using objective physical activity measures with youth: how many days of monitoring are needed? *Med Sci Sports Exerc* 2000;**32**(2):426-31.
58. Oliver M, Witten K, Kearns R, et al. Kids in the City Study: research design and methodology. *BMC public health* 2011;**11**(1):587.
59. Choi L, Liu Z, Matthews CE, Buchowski MS. Validation of accelerometer wear and nonwear time classification algorithm. *Med Sci Sports Exerc* 2011;**43**(2):357-64.
60. Evenson KR, Catellier DJ, Gill K, Ondrak KS, McMurray RG. Calibration of two objective measures of physical activity for children. *J Sports Sci* 2008;**26**(14):1557-65.
61. Trost SG, Loprinzi PD, Moore R, Pfeiffer KA. Comparison of accelerometer cut points for predicting activity intensity in youth. *Med Sci Sports Exerc* 2011;**43**(7):1360-68.
62. Cole T, Flegal KM, Nicholls D, Jackson AA. Body mass index cut offs to define thinness in children and adolescents: international survey. *BMJ* 2007;**335**(7612):194 doi: 10.1136/bmj.39238.399444published.
63. Inagami S, Cohen DA, Finch BK. Non-residential neighborhood exposures suppress neighborhood effects on self-rated health. *Soc Sci Med* 2007;**65**(8):1779-91.
64. Cummins S. Commentary: investigating neighbourhood effects on health—avoiding the 'local trap'. *Int J Epidemiol* 2007;**36**(2):355-57.
65. Kwan M-P. The uncertain geographic context problem. *Ann Assoc Am Geogr* 2012;**102**(5):958-68.
66. Chaix B, Méline J, Duncan S, et al. GPS tracking in neighborhood and health studies: A step forward for environmental exposure assessment, a step backward for causal inference? *Health & Place* 2013;**21**:46-51.
67. Golledge RG, Stimson RJ. Spatial Behavoir: A Geographical Perspective. New York: Guilford Press 1997.
68. Chaix B, Bean K, Leal C, et al. Individual/Neighborhood social factors and blood pressure in the RECORD cohort study which risk factors explain the associations? *Hypertension* 2010;**55**(3):769-75.
69. Chaix B, Billaudeau N, Thomas F, et al. Neighborhood effects on health: correcting bias from neighborhood effects on participation. *Epidemiology* 2011;**22**(1):18-26.
70. Chaix B, Kestens Y, Perchoux C, Karusisi N, Merlo J, Labadi K. An interactive mapping tool to assess individual mobility patterns in neighborhood studies. *Am J Prev Med* 2012;**43**(4):440-50.
71. Havard S, Reich BJ, Bean K, Chaix B. Social inequalities in residential exposure to road traffic noise: an environmental justice analysis based on the RECORD Cohort Study. *Occup Environ Med* 2011;**68**(5):366-74.

72. Duncan S, Stewart TI, Oliver M, et al. Portable Global Positioning System receivers: Static validity and environmental conditions. *Am J Prev Med* 2013;**44**(22):e19-e29.
73. Kerr J, Duncan S, Schipperjin J. Using Global Positioning Systems in health research: a practical approach to data collection and processing. *Am J Prev Med* 2011;**41**(5):532-40.
74. Brownson RC, Hoehner CM, Day K, Forsyth A, Sallis JF. Measuring the built environment for physical activity: State of the science. *Am J Prev Med* 2009;**36**(4):S99-S123. e12.
75. De Bourdeaudhuij I, Sallis JF, Saelens BE. Environmental correlates of physical activity in a sample of Belgian adults. *Am J Health Promot* 2003;**18**(1):83-92.
76. Leslie E, Saelens BE, Frank LD, et al. Residents' perceptions of walkability attributes in objectively different neighbourhoods: A pilot study. *Health & Place* 2005;**11**(3):227-36.
77. Saelens BE, Sallis JF, Black JB, Chen D. Neighbourhood-based differences in physical activity: An environment scale evaluation. *Am J Public Health* 2003;**93**(9):1552-58.
78. Cerin E, Conway TL, Cain KL, et al. Sharing good NEWS across the world: developing comparable scores across 12 countries for the neighborhood environment walkability scale (NEWS). *BMC Public Health* 2013;**13**(1):309.
79. Rosenberg D, Ding D, Sallis JF, et al. Neighborhood Environment Walkability Scale for Youth (NEWS-Y): reliability and relationship with physical activity. *Prev Med* 2009;**49**(2):213-18.
80. Van Der Horst K, Paw MJCA, Twisk JWR, Van Mechelen W. A brief review on correlates of physical activity and sedentariness in youth, 2007:1241.
81. Norman GJ, Schmid BA, Sallis JF, Calfas KJ, Patrick K. Psychosocial and environmental correlates of adolescent sedentary behaviors. *Pediatrics* 2005;**116**(4):908.
82. Grow HM, Saelens BE, Kerr J, Durant NH, Norman GJ, Sallis JF. Where are youth active? Roles of proximity, active transport, and built environment. *Med Sci Sports Exerc* 2008;**40**(12):2071.
83. Sallis J. The Active Where? Questionnaire. http://www.drjamessallis.sdsu.edu/measures.html 2005.
84. Frank L, Leerssen C, Chapman J, Contrino H. Strategies for metropolitan Atlanta's regional transportation and air quality (SMARTRAQ). *Atlanta, GA: Georgia Institute of Technology* 2001.
85. Prochaska JJ, Sallis JF, Long B. A physical activity screening measure for use with adolescents in primary care. *Archives of Pediatrics & Adolescent Medicine* 2001;**155**(5):554-59.
86. Norman GJ, Sallis JF, Gaskins R. Comparability and reliability of paper-and computer-based measures of psychosocial constructs for adolescent physical activity and sedentary behaviors. *Res Q Exerc Sport* 2005;**76**(3):315-23.
87. Sallis JF, Nader PR, Broyles SL, et al. Correlates of physical activity at home in Mexican-American and Anglo-American preschool children. *Health Psychol* 1993;**12**(5):390-98.
88. Marshall S, Biddle S, Sallis J, McKenzie T, Conway J. Clustering of sedentary behaviours and physical activity among youth: A cross-national study. *Pediatr Exerc Sci* 2002;**14**(410-417).
89. Duncan JS, Hopkins WG, Schofield G, Duncan EK. Effects of weather on pedometer-determined physical activity in children. *Med Sci Sports Exerc* 2008;**40**(8):1432.
90. Goldstein H, Browne W, Rasbash J. Multilevel modelling of medical data. *Stat Med* 2002;**21**(21):3291-315.
91. Burton P, Gurrin L, Sly P. Tutorial in biostatistics. Extending the simple linear regression model to account for correlated responses: an introduction to generalized estimating equations and multi-level mixed modeling. *Stat Med* 1998;**17**:1261-91.
92. Browne WJ, Draper D. A comparison of Bayesian and likelihood-based methods for fitting multilevel models. *Bayesian Analysis* 2006;**1**(3):473-514.
93. Austin PC. Estimating Multilevel Logistic Regression Models when the number of clusters is low: a comparison of different statistical software procedures. *Int J Biostats* 2010;**6**(1):1557-4679 doi: 10.2202/1557-4679.1195published.
94. Marrie RA, Dawson NV, Garland A. Quantile regression and restricted cubic splines are useful for exploring relationships between continuous variables. *J Clin Epidemiol* 2009;**62**(5):511-17. e1.
95. Attride-Stirling J. Thematic networks: an analytic tool for qualitative research. *Qual Res* 2001;**1**(3):385-405.

96. Östlund U, Kidd L, Wengström Y, Rowa-Dewar N. Combining qualitative and quantitative research within mixed method research designs: A methodological review. *Int J Nurs Stud* 2011;**48**(3):369.
97. Tashakkori A, Teddlie C. Handbook of mixed methods in social & behavioral research: Sage Publications, Inc, 2003.
98. Cohen DA, Ashwood S, Scott M, et al. Proximity to school and physical activity among middle school girls: the trial of activity for adolescent girls study. *Pediatrics* 2006;**118**(5):e1381.
99. Davison K, Lawson C. Do attributes in the physical environment influence children's physical activity? A review of the literature. *Int J Behav Nutr Phys Act* 2006;**3**(1):19.
100. Giles-Corti B, Kelty SF, Zubrick SR, Villanueva KP. Encouraging walking for transport and physical activity in children and adolescents. *Sports Med* 2009;**39**(12):995-1009.
101. Owen N, Cerin E, Leslie E, et al. Neighborhood walkability and the walking behavior of Australian adults. *Am J Prev Med* 2007;**33**(5):387-95.
102. Boarnet MG, Sarmiento S. Can land-use policy really affect travel behaviour? A study of the link between non-work travel and land-use characteristics. *Urban Studies* 1998;**35**(7):1155-69.
103. Cao X, Handy SL, Mokhtarian PL. The influences of the built environment and residential self-selection on pedestrian behavior: evidence from Austin, TX. *Transportation* 2006;**33**(1):1-20.
104. Handy S, Cao X, Mokhtarian PL. Self-selection in the relationship between the built environment and walking: Empirical evidence from Northern California. *J Am Plann Assoc* 2006;**72**(1):55-74.
105. Frank LD, Saelens BE, Powell KE, Chapman JE. Stepping towards causation: do built environments or neighborhood and travel preferences explain physical activity, driving, and obesity? *Soc Sci Med* 2007;**65**(9):1898-914.
106. Cao X, Mokhtarian PL, Handy SL. Examining the impacts of residential self□selection on travel behaviour: a focus on empirical findings. *Transport Reviews* 2009;**29**(3):359-95.
107. Yang T-C. Modifiable areal unit problem. *GIS Resource Document* 2005.
108. Waller LA, Gotway CA. Applied spatial statistics for public health data: John Wiley & Sons, 2004.
109. Weeks JR. The role of spatial analysis in demographic research. *Spatially integrated social science* 2004:381-99.
110. McCann B. Making physical activity research relevant to policy makers. *J Phys Act Health* 2006;**3**(Supp1):S267-S72.
111. Brownson RC, Jones E. Bridging the gap: translating research into policy and practice. *Prev Med* 2009;**49**(4):313-15.

STROBE Statement—Checklist of items that should be included in reports of ***cross-sectional studies***

	Item No	Recommendation
Title and abstract	1	✓ (*a*) Indicate the study's design with a commonly used term in the title or the abstract
		✓ (*b*) Provide in the abstract an informative and balanced summary of what was done and what was found
Introduction		
Background/rationale	2	✓ Explain the scientific background and rationale for the investigation being reported
Objectives	3	✓ State specific objectives, including any prespecified hypotheses
Methods		
Study design	4	✓ Present key elements of study design early in the paper
Setting	5	✓ Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection
Participants	6	✓ (*a*) Give the eligibility criteria, and the sources and methods of selection of participants
Variables	7	✓ Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable
Data sources/ measurement	8*	✓ For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group
Bias	9	✓ Describe any efforts to address potential sources of bias
Study size	10	✓ Explain how the study size was arrived at
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why
Statistical methods	12	✓ (*a*) Describe all statistical methods, including those used to control for confounding
		(*b*) Describe any methods used to examine subgroups and interactions
		(*c*) Explain how missing data were addressed
		(*d*) If applicable, describe analytical methods taking account of sampling strategy
		(*e*) Describe any sensitivity analyses
Results		
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed
		(b) Give reasons for non-participation at each stage
		(c) Consider use of a flow diagram
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders
		(b) Indicate number of participants with missing data for each variable of interest
Outcome data	15*	Report numbers of outcome events or summary measures
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included
		(*b*) Report category boundaries when continuous variables were categorized
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a

		meaningful time period
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses
Discussion		
Key results	18	✓ Summarise key results with reference to study objectives
Limitations	19	✓ Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence
Generalisability	21	✓ Discuss the generalisability (external validity) of the study results
Other information		
Funding	22	✓ Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based

*Give information separately for exposed and unexposed groups.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.