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ABSTRACT

Background: Exposure to green space has been associated with increased physical activity. However, it is not clear whether this association is because active people preferentially live in greener areas. Relationships between exposure to green space and physical activity during pregnancy are not well defined. Our objective was to determine whether exposure to green space was associated with physical activity in pregnant women. **Methods:** The current study was completed within the *Growing Up in New Zealand* cohort study of 6772 pregnant women. The proportion of green space in each census area unit was determined and geocoded to residential address. The association between exposure to green space and physical activity was determined using logistic regression analyses after controlling for confounding variables. **Results:** Exposure to green space was not associated with participation in physical activity during first trimester and the remainder of pregnancy once preference for living in greener neighborhoods was taken into account. **Conclusions:** The lack of association between green space and physical activity found in this study does not necessarily mean that living in green space will not translate into better pregnancy health. Preference for living in greener neighborhoods should be considered when investigating relationships between green space and physical activity.

INTRODUCTION

Green space is defined by the United States Environmental Protection Agency as "land that is partly or completely covered with grass, trees, shrubs, or other vegetation", including parks, community gardens, and cemeteries.[1] The importance of establishing and maintaining green spaces has been acknowledged in public policy in the United Kingdom and in European countries.[2] In cities, the availability of green space is related to the city area, with more

compact cities tending to have very low levels of per capita green space.[3] However, the per capita availability of green space has been found to display only a weak inverse relationship with population density.[3]

Exposure to green space in the general population is linked to improved societal outcomes, including increased social coherence and local social interaction,[4] stronger social ties,[5] and reduced crime and violence.[6] More specifically, exposure to green space in adults in the general population results in measurable benefits to both physical and psychological health.[7] Health benefits that have been shown to be associated with exposure to green space include better self-reported general health,[8] a decreased risk of obesity,[9] a decreased risk of Type 2 diabetes,[10] and a reduction in short sleep duration.[11] One potential mechanism by which green spaces can exert a positive impact on health is through enabling physical activity.[12] However, there is a lack of consensus as to whether exposure to green space increases participation in physical activity. Some studies conducted in the general population describe that it does[13-15] while others do not.[16-18]

Exposure to green space in specific populations such as pregnant women has been shown to be associated with health benefits.[19-22] Pregnancy is a life phase when there is a greater focus on health and the potential for this focus to lead to improved health.[23] Moderate intensity physical activity during pregnancy is associated with improved mood and self-image; more sleep; more appropriate weight gain; improved muscle tone, strength and endurance; increased energy levels during labor and delivery and more rapid recovery following labor and delivery.[24] Currently there are limited published data investigating the relationship between exposure to green space and the physical activity levels of pregnant women.[22]

In the general population, the beneficial effects of green space exposure appear to be more pronounced for people residing in more socioeconomically deprived areas.[25,26] Of particular relevance to the reduction in disparities in health between population subgroups is that exposure to green space is potentially a more important determinant of pregnancy health for people living in poorer socioeconomic situations. In a socioeconomically diverse birth cohort enrolled in Barcelona, Spain, closer proximity to large areas of green space and increased surrounding greenness were not associated with increased birth weight for the entire cohort, but were when considering only infants born to women in the least educated group.[21] In a more recent study of the association between green space and depression, both exposure to green space and proximity to residential greenness during pregnancy were shown to be related to reduced incidence of depression in the entire cohort of pregnant women.[22] The associations between exposure to residential greenness and less depression were stronger for pregnant women who had attained fewer than five general certificates of secondary education as their highest educational qualification and who were physically active.[22] However, *proximity* to green space was not associated with less depression for pregnant women with fewer than five general certificates of secondary education who were physically active.[22]

In New Zealand, people living in the most deprived socioeconomic areas tend to live in closer proximity to recreational amenities (parks, sports and leisure facilities, and beaches) than those living in the least deprived socioeconomic areas.[27] The median travel time by car to parks, sports, and leisure facilities is significantly lower for residents living in the most compared with the least deprived areas (1.11 vs 1.56 min for parks [$p < .001$]; 4.15 vs 6.69 min for sports and leisure amenities [$p < .001$]).[27] In the general population in New Zealand, the availability of green space has been shown to not be an important determinant of health

for people residing in the most, moderately, and least deprived areas.[28,29] This may be because New Zealand is a very green country.[30]

The objective of the study reported here was to determine whether exposure to green space was associated with physical activity levels in pregnant women, taking into consideration both their preference for the local lifestyle of the neighborhood (used as a measure of endogeneity) and their socioeconomic status.

MATERIALS AND METHODS

Data Source: *Growing Up in New Zealand*

This research study was completed within New Zealand's contemporary child cohort study *Growing Up in New Zealand*.[31] The cohort was created through the recruitment of 6822 pregnant women whose expected delivery date was between April 2009 and March 2010, and who resided within a geographical region defined by three adjacent District Health Boards: Auckland, Counties-Manukau and Waikato.[32] This region was selected to enable the enrollment of a sample with sufficient diversity to have adequate explanatory power for analyses within socioeconomic and ethnic population subgroups.[33]

Eligibility was defined by residence during pregnancy within the study region.[33] The cohort of 6853 children born to these 6822 women represented 11% of births in New Zealand over the study recruitment period.[33] Ethical approval for *Growing Up in New Zealand* was granted by the Ministry of Health Northern Y Regional Ethics Committee (NTY/08/06/055), and written informed consent was obtained from all enrolled mothers.[33] *Growing Up in New Zealand* is also being utilized as a data source in other studies,[31] including a separate study

investigating whether increased exposure to green space in pregnant women is associated with birth weight and gestational age.

Data collection and measurement of variables

Data describing demographics and household characteristics were collected using face-to-face computer-assisted personal interviews.[31] Pregnant women were usually interviewed in their home.

Each maternal participant's residential address was geocoded to a Census Area Unit (CAU). The available green space within each CAU was quantified using the geographic information system (ArcGIS). Each CAU is a collection of mesh blocks which are the smallest census geographical units in New Zealand. Census area units are defined as "non-administrative areas that are in between mesh blocks and territorial authorities in size." They are the second smallest geographical units used in New Zealand. Each urban CAU in New Zealand has a population of 3000 to 5000.[34] A small number of the maternal participants (n = 50) in the *Growing Up in New Zealand* study resided in CAUs outside of the study region, and were not included in the analyses. The final sample, after this exclusion, consisted of 6772 pregnant women. Of these, 83% were interviewed prior to the cohort child's birth (n = 5615) and the remaining 17% (n = 1157) after the cohort child's birth.

The minimum levels of physical activity for adults aged 18 to 65 years recommended by the American College of Sports Medicine and the American Heart Association are 150 minutes/week of moderate or 60 minutes/week of vigorous physical activity, with the duration of each session of physical activity being 10 minutes or more.[35] The American College of Obstetricians and Gynecologists (ACOGs) suggests that pregnant women without any medical or obstetric complications should engage in physical activity, of at least

moderate intensity, for at least 30 minutes on most, if not all, days of the week.[36] In this study, the levels of physical activity during pregnancy were self-reported using the short version of the International Physical Activity Questionnaire (IPAQ).[37] The reliability and validity of this version of the IPAQ have been established for the measurement of physical activity in both the general population[38] and in pregnant women.[39,40]

Conceptual framework of cohort study

The conceptual model of *Growing Up in New Zealand* was deliberately designed to understand the dynamic interactions between each child and their environment across a broad range of influences from the immediate family environment to the wider societal context. To achieve this, research constructs were created within six research domains: (i) health and well-being, (ii) psychosocial and cognitive development, (iii) education, (iv) family, (v) culture and identity, and (vi) the societal context.[33] Within the societal context, characteristics of the neighborhood in which the family lived and also parental perception of and participation in their neighborhood were measured.[33]

Independent variables (confounders)

The independent variables considered in this study were those that described exposure to green space, maternal demographics (age, ethnicity, education, and employment status), and household characteristics, socioeconomic status, preference for the local lifestyle of the neighborhood, residential rurality, and geographical mobility as defined by years of residence in the current neighborhood.[33]

Classification and measurement of potentially confounding variables

Education was classified into two levels: non-tertiary and tertiary. Tertiary education was defined as all post-school education including diploma, bachelor, and higher degrees.[41] For

the analyses presented here, ethnicity was defined as self-prioritized ethnicity, gathered from each maternal participant at the most detailed level possible, and then coded into six Level 1 categories following the Statistics New Zealand coding criteria: (1) European, (2) Māori (New Zealand's indigenous population), (3) Pacific, (4) Asian, (5) Middle Eastern, Latin American and African, and (6) New Zealander or Other.[31]

To determine parental perception of their neighborhood, information was gathered on why people currently lived in a particular location.[33] Questions were informed by an earlier qualitative study completed in Auckland on socio-geographical dimensions of New Zealand neighborhoods and caregiver access to community resources,[42] and the Los Angeles Study of Families and Neighborhoods.[43]

In the current study, the neighborhood self-selection variable was described as the preference for the local lifestyle of the neighborhood. It was worded as, "Why do you live in this neighborhood?: I like the local lifestyle". Respondents were asked to respond "yes" or "no" depending on whether they preferred to live in their neighborhood because of its lifestyle, including locational access to community resources (ie, access to green spaces and other recreational, public transport, shopping, education, health care, and social and cultural facilities). This variable was used as a proxy measure of endogeneity as it represents, at least in part, a participant's preference for living in a neighborhood with better locational access to green spaces and other recreational facilities.

Socioeconomic status was measured using the New Zealand Index of Deprivation, NZDep2006.[44] This index is a small area measure of deprivation derived from variables collected at the 2006 national census. NZDep2006 is an ordinal scale from 1 to 10 (1 = area of least deprivation; 10 = area of most deprivation).[44] For statistical analyses, these deciles

were grouped into low, medium, and high deprivation (Low: deciles 1-3, Medium: deciles 4-7, High: deciles 8-10).

Classification and measurement of green spaces

Green spaces were defined as areas that are definitely or possibly able to be used for the purpose of physical activity. Parks, beaches, and urban parklands/open spaces were considered areas that are definitely used for physical activity. Beaches were classified as green spaces as they are easily accessible by road, and used by people for engaging in physical activity. Green spaces such as forests, grasslands, and croplands were considered areas that are possibly used for physical activity. The areas surrounding green spaces of other land-use types ("non-green spaces") were excluded from the analyses. These non-green spaces included built-up or settlement areas, transport infrastructures, and water bodies. An example of green space classification is presented in Figure 1.

Data on green spaces in Auckland and Counties-Manukau District Health Board regions were obtained from the Auckland Council. This particular feature class was an amalgamation of a few different existing sources (eg, public open space zones from the operative district plans and the proposed unitary plan, and reserves derived from Land Information New Zealand). Metadata on green spaces in the Auckland and Counties-Manukau District Health Board regions were not available from the providers. Data on green spaces in the Waikato District Health Board region were obtained from the Waikato District Council and provide an accurate representation of the Waikato District Council's recreation reserve network with a scale of 1:50,000 and an accuracy of 90.0%. In addition, data on green spaces were obtained from the New Zealand Land Cover Database (LCDB) of the Land Resource Information Systems portal.[45] National datasets, such as the LCDB, tend to provide more attributes than

data from councils. The scale of the LCDB is 1:50,000 and the minimum mapping unit is one hectare. Its overall user accuracy is 93.9%.[45]

To account for the daily variability in exposure to green space, the percentages of green space were calculated for each CAU rather than each mesh block. Such a measure of green space exposure has been used in previous studies in New Zealand.[14,28] The digital boundary shaped files (CAU files for New Zealand) were downloaded from Statistics New Zealand.[46] These were clipped to the Auckland and Waikato regions using regional shape files from Statistics New Zealand.[46] The union and dissolve tools in ArcGIS were used to determine the proportion of green space in each CAU.[47] The 25th, 50th, and 75th percentiles were used as break points for the categorization of green space, and selected to ensure an approximately equal number of maternal participants in each category of green space. This approach enabled comparability with previous studies in New Zealand in which green space was categorized into quartiles.[14,28] In the present study, the cut-offs for percentage of green space that divided the study sample into quartiles categorized green space as low (0- < 12%), medium (12- < 21%), high (21- < 38%), or very high (38-100%). All analyses were conducted in ArcGIS (ESRI, Redlands, California, USA) Version 10.2.

STATISTICAL ANALYSES

Moderate or vigorous physical activity for pregnant women

Each woman was asked to estimate the frequency and duration of both the moderate and vigorous physical activity in which they engaged at three time intervals: before their pregnancy; during the first three months of their pregnancy; and for the remainder of their pregnancy. This information was collected only at one time at either the end of their pregnancy or shortly after the cohort child's birth. The frequency and duration of moderate or

vigorous physical activity engaged in at each of these time intervals were dichotomized as 0 (not meeting the ACOG guidelines for frequency and duration) or 1 (meeting the ACOG guidelines for frequency and duration).[36] The dichotomized frequency and duration variables created for physical activity were then combined to produce a single variable that represented whether recommendations for participation in moderate or vigorous physical activity were met (0 = not physically active; 1 = physically active). The dependent variables used in the regression analyses for physical activity were these variables that described moderate or vigorous physical activity, with separate regression analyses for the first trimester and the remainder of the pregnancy. As physical activity differs across trimesters of pregnancy,[48,49] this trimester separation was considered necessary.

Associations of exposure to green space with levels of physical activity for pregnant women

All independent variables were expressed as categorical variables. A series of logistic regression models was created to investigate associations of green space with levels of physical activity. Univariate logistic regression analyses were first conducted (unadjusted) (Model 1). The green space variable was included in Model 2, as were variables describing age, ethnicity, education, and employment status. Model 3 was similar to Model 2 with the addition of the variable describing household deprivation (NZDep2006). Model 4 was similar to Model 3 with the addition of the variable describing preference for the local lifestyle of the neighborhood.

Interactions were tested between the exposure variable (green space) and age, ethnicity, education, and NZDep2006. Likelihood ratio tests were performed to investigate whether the final regression models were a better fit without interaction terms. Interaction terms were

included in Model 4 if they were found to be statistically significant at a *p*-value of .05. Co-linearity was tested for all variables included in Model 4 (the final model). Independent associations were described using adjusted odds ratios (ORs) and 95% confidence intervals (CIs). Four sensitivity analyses were conducted for: (1) Interview period during or after pregnancy; (2) Urban or rural area of residence; (3) NZDep2006 groups of low, medium, and high; and (4) Analyses that considered moderate and vigorous physical activity separately. The statistical software Stata Version 13.1 (Stata Corp LP, Texas) and SPSS Version 22 (IBM, New York) were used for the analyses.

RESULTS

Green space exposure for pregnant women

The census area units of the Auckland and Counties-Manukau District Health Board regions (n = 413) had a median area of 1.62 km^2 (range = 0.20 to 592.46 km^2) while the CAUs of the Waikato District Health Board region (n = 200) had a median area of 6.64 km^2 (range = 0.14 to 1233.76 km^2). The mean (standard deviation [SD]) percentage of green space in all of the CAUs of the Auckland and Counties-Manukau District Health Board regions (n = 413) was 38% (32%) and for the Waikato District Health Board region (n = 200) 65% (34%). There were significant differences between population subgroups defined by NZDep2006 in their exposure to green space ($F = 172.79$; $p < .001$). The percentage of green space decreased by 2.12% ($p < .001$) with each decile increase in house deprivation score.

Demographics and bivariate analyses for moderate or vigorous physical activity during the first trimester and the remainder of pregnancy

The mean (SD) maternal age was 30 (6) years. Sixty-nine percent had attained some form of tertiary education and 54% were employed. Fifty-three percent of the women described their self-prioritized ethnicity as European. The mean (SD) duration of residence at the nominated address was 4 (6) years. Thirty-one percent of the women lived in their neighborhood because they preferred its local lifestyle.

A two-way table with a measure of the association between preference of the local lifestyle of the neighborhood and NZDep2006 showed that women who preferred the local lifestyle of the neighborhood lived more frequently in low (38.8%) or medium deprivation areas (40.8%). Additionally, significant differences existed between population subgroups defined by NZDep2006 in their preference for the local lifestyle of the neighborhood, confirming that these two variables were not independent ($\chi^2 = 523.56$; $p < .0001$). Univariate logistic regression analysis revealed that the women residing in medium and high deprivation areas were less likely to prefer the local lifestyle of the neighborhood than women residing in low deprivation areas (OR = 0.56 [95% CI = 0.49–0.64] and OR = 0.21 [95% CI = 0.18–0.24], respectively). Preference for the local lifestyle of the neighborhood was independently associated with green space ($\chi^2 = 166.34$; $p < .0001$), and with moderate or vigorous physical activity after the first trimester of pregnancy ($\chi^2 = 5.31$; $p = .021$), but not with moderate or vigorous physical activity during the first trimester of pregnancy ($\chi^2 = 2.91$; $p = .088$). Consistent with the national data describing the deprivation of New Zealand households of families with young children, households in the most deprived three deciles were over represented.[50] Unadjusted bivariate analyses of the associations of demographic characteristics with moderate or vigorous physical activity during the first trimester and the remainder of pregnancy are presented in Table 1.

Participation in physical activity by pregnant women

Moderate and vigorous physical activity decreased from the pre-pregnancy period (moderate 25%, vigorous 39%) to the first trimester (moderate 17%, vigorous 16%) and further to the remainder of the pregnancy based on the entire cohort (moderate 15%, vigorous 9%) (Table 2). Significant differences were present across the three time intervals (before pregnancy, the first trimester, and during the remainder of the pregnancy) for both moderate and vigorous physical activity ($p < .0001$ for all time interval comparisons of moderate and of vigorous physical activity). Significant differences persisted across the three time intervals for both moderate and vigorous physical activity after stratification of analysis based on quartiles of green space.

Interaction analysis and association of green space with physical activity for women during the first trimester and the remainder of the pregnancy

No interaction was evident between green space and other independent variables (age, education, self-prioritized ethnicity, and NZDep2006), implying these did not modify the association between green space and physical activity.

Women living in CAUs with very high levels of green space were more likely to meet recommendations for moderate or vigorous physical activity (OR = 1.26; 95% CI = 1.09–1.47) during the first trimester than were women living in areas with low levels of green space (Model 1). Participation in moderate or vigorous physical activity by women during the remainder of pregnancy was not associated with green space.

The fully adjusted multivariate regression analysis (Model 4) showed that exposure to very high levels of green space was not associated with moderate or vigorous physical activity

either during (OR = 1.16; 95% CI = 0.99–1.36) or after (OR 1.04; 95% CI = 0.88–1.24) the first trimester of pregnancy.

Sensitivity analyses

Each of the four sensitivity analyses did not result in any change in the findings from Model 4, with no association evident between green space and physical activity in any of these sensitivity analyses.

DISCUSSION

Main findings

This study investigated the associations between exposure to green space and the physical activity patterns of New Zealand pregnant women and the role that socioeconomic status plays in these associations. In this socioeconomically and ethnically diverse cohort, participation in moderate and vigorous physical activity decreased from the pre-pregnancy period to the first trimester and further during the remainder of the pregnancy. This reduction in physical activity is consistent with previous pregnancy studies.[48,49] Contributing factors that have been identified include tiredness, lack of time, feeling unwell, and feeling uncomfortable.[48] In the present study, the decrease in physical activity was observed for all quartiles of green space.

In this current study, exposure to green space varied by New Zealand area-level deprivation, with green space decreasing as deprivation increased. This is in line with previous research on green space and socioeconomic status both within New Zealand[28] and internationally.[21,51]

In Spain and England, pregnant women living in the least deprived neighborhoods experienced higher residential surrounding greenness (defined as the average of Normalized Difference Vegetation Index [NDVI] in a buffer of 100 m around each maternal address) than did pregnant women living in the most deprived neighborhoods.[21,51] In New Zealand, in a study of the association between green space and cause-specific mortality for adults aged 15 to 64 years, a socioeconomic gradient in exposure to green space was evident, with the percentage of total green space decreasing by 11%, but the percentage of useable green space increasing marginally by 2%, with each quintile increase in NZDep2001 deprivation score.[28]

Comparison of study results with previous studies

Three previous cross-sectional studies in the general population, from Australia, England and New Zealand, have investigated the relationship between exposure to green space and physical activity.[13-15] These studies used measures of exposure to green space that are comparable to what the current study used, but in none of these studies was any measure of endogeneity included. The Australian study revealed that participants residing in greener areas were more likely to participate in walking (incidence rate ratio [IRR] = 1.09) and moderate-to-vigorous physical activity (IRR = 1.10) than were participants residing in the least green areas.[15] The study from England showed that participants living in the greenest quintile were more likely to perform five sessions of moderate or vigorous physical activity of at least 30 minutes duration in each week than were participants living in the least green quintile (OR = 1.24).[13] The New Zealand study, using data collected from adults in the 2006 and 2007 New Zealand Health Survey, investigated whether physical activity mediated the association between greenness in CAUs and morbidity outcomes (obesity, poor general health, poor mental health, and cardiovascular disease).[14] Physical activity was shown to

partially mediate the association between exposure to green space and the risk of poor mental health and cardiovascular disease.[14]

Whether physical activity mediated the relationship between green space and pregnancy health was investigated in the "Born in Bradford" cohort study from England by examining the effect of residential greenness (defined as average NDVI in buffers of 100, 300, and 500 m around maternal address) and proximity to green space (defined as living within 300 m of major green space) on depression in a cohort of pregnant women, and investigated whether physical activity mediated the association between green space and depression.[22] Pregnant women living in greener quintiles were 18% to 23% less likely to report depression than were pregnant women living in the least green quintile. Pregnant women living within 300 m of major green spaces were 13% less likely to report depression than others. Associations between residential greenness and depression were robust for pregnant women with low educational qualifications and those who were physically active.[22] Physical activity was shown to partially mediate the association between green space and depression.[22]

In contrast with these studies, and consistent with both general adult[13-15] and pregnant population studies,[22] findings of this current study show that once neighborhood preference is taken into consideration, green space exposure has no significant impact on the extent to which pregnant women engage in moderate or vigorous physical activity, irrespective of their socioeconomic background.

A possible alternative explanation for the lack of agreement of our findings with the results of previous studies[13-15,22] is the inclusion of different types of green spaces. Areas such as grasslands were not included in the classification of green spaces in the general adult population studies from England.[13] Neither grasslands nor croplands were included in the classification of green spaces in general adult population studies from Australia,[15] New

Zealand,[14] nor in the pregnant population studies from England.[22] In contrast with previous studies, the current study included all types of green space in the definition of green spaces.

Strengths and limitations

This is the first study in New Zealand that has investigated the association between physical activity and green space exposure among pregnant women. Adjustment was made for multiple potentially confounding factors including preference for the local lifestyle of the neighborhood. The green space data in this research were linked to a large and diverse cohort with physical activity and key demographic variables characterized by robust measures. Because of its cohort design, data are subject to less sampling bias than would potentially be introduced in other sampling methodologies (eg, postal questionnaires).

The current study has some limitations. The measure of green space was based on calculating the proportion of green space in CAUs. As these areas can be large, the higher percentage of green space might not necessarily transform into proximity to green space. Measures of household income, occupation, and body mass index during pregnancy could not be included in the regression models due to a high proportion of missing observations for these variables. Both income and occupation are important components of personal-level socioeconomic status,[52] and body mass index has been shown to be an important determinant of physical activity.[53]

Objective measurements of physical activity could have provided more precise estimates of physical activity.[54] Also, this study could not describe green space quality. The quality of green spaces (safety, esthetics, amenities, and maintenance) has been shown to be an important determinant of the use of green spaces for physical activity.[55] The inability to

determine whether the green spaces were actually used for engagement in physical activity was another limitation. Future researchers could ask participants about the nature and location of the places in which physical activity takes place. Preference for the local lifestyle of the neighborhood is an imperfect measure of endogeneity. Its limitation is that it also represents participant's preference for living in a neighborhood with better locational access to facilities other than green spaces and other recreational facilities (eg, public transport, education, or health care facilities), not green space alone.

Conclusions, implications for urban planners, and future directions

The current findings suggest that, in New Zealand, having more green space in proximity to residence is not associated with increased physical activity during pregnancy, irrespective of socioeconomic status and after adjustment for preference for the lifestyle of the neighborhood. However, despite lack of association between exposure to green space and physical activity, living in green space could still translate into better pregnancy health.

The findings of this study have implications for urban planners to ensure there are enough green spaces so that pregnant women who want to live in them can do so (a supply and demand issue). Further studies are needed that overcome the present study's limitations. Future research should use objective measurements of physical activity; include measures of green space quality; and include more robust measures of endogeneity. Insights into the relationship between exposure to green space and physical activity could be gained by analyzing a subset of pregnant women migrating from less to more green areas.

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Table 1: Description of the maternal participants and unadjusted bivariate tests for physical activity during the first trimester (bivariate analyses 1) and the remainder of pregnancy (bivariate analyses 2)

Variables (N = 6772)*	Descriptive	Bivariate analyses 1	Bivariate analyses 2
Demographics:			
Age at enrolment in years	**n (%)**	**chi square (*p*-value)**	**chi square (*p*-value)**
< 20	325 (5)		
20-24	992 (15)		
25-29	1651 (24)		
30-34	2108 (31)	6.90 (.228)	5.60 (.35)
35-39	1411 (21)		
≥ 40	285 (4)		
Highest education			
No secondary school	485 (7)		
Secondary school	1610 (24)		
Diploma	2068 (30)	23.74 (< .0001)	4.11 (.39)
Bachelor's degree	1532 (23)		
Higher degree	1058 (16)		
Employment status			
Employed	3636 (54)		
Unemployed	543 (8)		
Student	455 (7)	14.33 (.002)	11.40 (.010)
Not in workforce	1822 (27)		
Self-prioritized ethnicity			
European	3576 (53)		
Māori	933 (14)		
Pacific	1001 (15)	85.48 (< .0001)	27.67 (< .0001)
Asian	1002 (15)		
Middle Eastern/Latin American/African	145 (2)		
Other or New Zealander	96 (1)		
Household characteristics:			
Deprivation index			
≤ 3: low	1684 (25)		
4-7: medium	2471 (36)	0.73 (.70)	0.87 (.65)
8-10: high	2615 (39)		
Preference for the local lifestyle of the neighborhood			
No	4615 (68)		
Yes	2135 (31)	2.91 (.088)	5.31 (.021)
Residential rurality			
Urban	6325 (93)		
Rural	447 (7)	20.95 (< .0001)	9.32 (.002)
Green space percentage in census area units:			
Green space percentage			
Low	1672 (25)		
Medium	1652 (24)	13.00 (.005)	8.06 (.045)
High	1764 (26)		
Very High	1684 (25)		

* Percentages do not add to 100% as the proportion of missing data is from 0.0%-9.4% for pregnant women.

Table 2: Participation in physical activity by the pregnant women before and during pregnancy

Adherence to recommendations for frequency and duration of physical activity before and during pregnancy for pregnant women					
	LGS	**MGS**	**HGS**	**VHGS**	**Total Population**
Pre-pregnancy period	**n (%)**	**n (%)**	**n (%)**	**n (%)**	**n (%)**
Met recommendations for:					
Moderate physical activity[1]	397 (26)	373 (25)	438 (28)	512 (33)	1720 (25)
Vigorous physical activity[2]	603 (40)	621 (42)	670 (42)	734 (47)	2628 (39)
Moderate or vigorous physical activity[3]	816 (54)	824 (56)	903 (57)	947 (61)	3490 (52)
First trimester of pregnancy					
Met recommendations for:					
Moderate physical activity[1]	269 (18)	237 (16)	298 (19)	334 (21)	1138 (17)
Vigorous physical activity[2]	244 (16)	249 (17)	274 (17)	319 (20)	1086 (16)
Moderate or vigorous physical activity[3]	437 (29)	429 (29)	491 (31)	533 (34)	1890 (28)
Remainder of pregnancy					
Met recommendations for:					
Moderate physical activity[1]	236 (16)	216 (15)	266 (17)	282 (18)	1000 (15)
Vigorous physical activity[2]	153 (10)	122 (8)	159 (10)	183 (12)	617 (9)
Moderate or vigorous physical activity[3]	351 (23)	312 (21)	375 (24)	395 (25)	1433 (21)

1 = Moderate physical activity for 150 minutes per week; 2 = Vigorous physical activity for 60 minutes per week; 3 = Moderate physical activity for 150 minutes or vigorous physical activity for 60 minutes per week.

LGS = low green space; MGS = medium green space; HGS = high green space; VHGS = very high green space.

Table 3: Associations between green space and physical activity for pregnant women during the first trimester and after the first trimester of pregnancy

Associations of green space with meeting recommendations for frequency and duration of moderate or vigorous physical activity				
Independent variable	**Model 1[a]**	**Model 2[b]**	**Model 3[c]**	**Model 4[d]**
Whether recommendations were met for moderate or vigorous physical activity during the first trimester of pregnancy[1]				
Green space percentage in census area unit	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)
Low	1.00	1.00	1.00	1.00
Medium	0.99 (0.84-1.16)	0.93 (0.79-1.09)	0.93 (0.79-1.09)	0.93 (0.79-1.09)
High	1.08 (0.93-1.26)	1.01 (0.86-1.18)	1.01 (0.87-1.19)	1.02 (0.87-1.19)
Very high	**1.26 (1.09-1.47)**	1.17 (0.99-1.37)	**1.17 (1.01-1.38)**	1.16 (0.99-1.36)
Whether recommendations were met for moderate or vigorous physical activity after the first trimester of pregnancy[1]				
Green space percentage in census area unit	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)
Low	1.00	1.00	1.00	1.00
Medium	0.87 (0.73-1.03)	0.85 (0.71-1.01)	0.85 (0.71-1.01)	0.85 (0.72-1.02)
High	1.01 (0.85-1.19)	0.98 (0.83-1.16)	0.98 (0.83-1.16)	0.98 (0.83-1.17)
Very high	1.11 (0.94-1.31)	1.06 (0.89-1.26)	1.07 (0.90-1.27)	1.04 (0.88-1.24)

a = unadjusted univariate

b = adjusted for age, ethnicity, education, and employment status

c = adjusted for age, ethnicity, education, employment status, and NZDep2006

d = adjusted for age, ethnicity, education, employment status, NZDep2006, and preference for the local lifestyle of the neighborhood.

1 = Moderate physical activity for 150 minutes per week or vigorous physical activity for 60 minutes per week.

OR = odds ratio; CI = confidence interval; **Highlighted bold ORs are significant at *p*-value of .05.**

Figure 1: An example of green space classification for Auckland and Counties -Manukau District Health Board regions of New Zealand