Association between the number of physical activity outlets, physical activity intensity opportunities, and obesity prevalence in Aotearoa/New Zealand

Author

Jani, Rati, Mhaskar, Kshemina, Williams, Margaret, Dasgupta, Poulami, Al-Foraih, Meisa, Knight-Agarwal, Catherine, Rush, Elaine, Simmons, David

Published

2022

Journal Title

International Public Health Journal

Version

Accepted Manuscript (AM)

Running title: Physical activity and obesity

Association between the number of physical activity outlets, physical activity intensity opportunities and obesity prevalence in Aotearoa/New Zealand

Rati Jani[1], PhD, AdvAPD, Kshemina Mhaskar[1], MSc, Margaret H Williams[2], PhD, Poulami Dasgupta[1], MSc, Meisa Al-Foraih[1], PhD, Cathy K Agarwal[1], PhD, AdvAPD, Elaine Rush[3], PhD, APD and David Simmons[4], PhD, MD

[1]*Faculty of Health, Department of Nutrition and Dietetics, University of Canberra, Australia,* [2]*Public Health & Interdisciplinary Studies Auckland University of Technology, New Zealand,* [3]*Centre for Physical Activity and Nutrition, Auckland University of Technology, New Zealand,* [4]*School of Medicine, Western Sydney University, Australia*

Abstract: We examined the association between availability (count), proxy physical activity intensity opportunities from physical activity outlets and obesity prevalence in New Zealand. This cross-sectional study collected data from two urban and 51 rural geographical locations in Waikato and Lakes District (May 2004-March 2006). Physical activity outlets were recorded by referring to online business directory and Waikato and Lakes District Councils database and confirming it with expert Māori community health workers. METs (Metabolic equivalent of task) was used as a proxy indicator to signify the physical activity intensity opportunity offered by physical activity outlets, which was averaged to obtain a unified score for each geographic location. Information regarding median income and type of location was derived from 2006 New Zealand census of Population and Dwelling. Bivariate analysis reported a significant difference in obesity prevalence using Māori BMI cut-offs between clusters with proxy METs <5.12 (n=15) and proxy METs ≥5.12 (n=10), 56.20±0.22 vs 43.30±0.07% obesity prevalence, t(17.77)=1.45, p=0.03. This inverse relationship between low physical activity intensity opportunity (proxy METs) and percent obesity prevalence remained significant after controlling for income and type of locality (β=-0.421, p=0.03). Furthermore, results highlighted that low income (below the median, ≤ NZ $24,400), moderated the inverse relationship between mean METs proxy indicator and obesity prevalence using Māori BMI cut-offs, *b*=-0.4661, 95% CI (-0.6054, -0.3268, p<0.001). These findings support the development of physical activity related public health programs in low-income Māori communities in New Zealand to manage obesity prevalence.

Keywords: Obesity, physical activity, Māori, METs, New Zealand

Correspondence: Dr Rati Jani, PhD, AdvAPD, Faculty of Health, Department of Nutrition and Dietetics, University of Canberra, Room no. 20, level B, University of Canberra Hospital, University Drive, Bruce, ACT, Australia, 2617. E-mail: Rati.Jani@canberra.edu.au

Introduction

Six hundred and fifty million adults are obese worldwide (1). The New Zealand Health Survey 2019/2020 reported approximately one third (30.9%) of adults are obese (2). Obesity among the Māori ethnic group is significantly higher (47.9%) compared to European New Zealanders (29.3%) (2). The New Zealand Health Survey identified that adults living in socioeconomically deprived areas (e.g., lower income status) were 1.8 times more likely to be obese compared to adults living outside of these areas (2). Furthermore, the New Zealand Index of Deprivation reported higher proportions of Māori (23.5%) living in socioeconomically deprived areas of New Zealand compared to non-Māori (6.8%) (3).

A high incidence of co-comorbidities is associated with obesity. A meta-analysis of 89 prospective cohort studies reported obesity to be associated with the incidence of cardiovascular diseases, type II diabetes, cancers, chronic back pain, gallbladder diseases and osteoarthritis (4). Furthermore, the economic costs associated with obesity debilitates the healthcare system (5). In 2006, New Zealand health care expenditure due to overweight and obesity was approximately $624 million (6). Overweight and obesity within the Māori population accounted for 18.5% of the total health care expenditure (5, 6). The Analysis Grid for Environments Linked to Obesity (ANGELO) Framework identifies micro level (e.g., proximal factors of obesity affiliated with school, workplace, home, etc) and macro level (distal factors of obesity affiliated with the health care system, urban planning, media, etc) determinants of obesity (7). The availability and price of healthier food choices has previously been investigated as a determinant of obesity by the authors (8). This paper focuses on availability of physical activity opportunities as a macro level determinant of obesity.

Existing literature has examined the association between availability of physical activity opportunities and obesity prevalence. A systematic review of 92 studies, predominantly cross-sectional from the United States reported an inverse association between physical activity opportunities (e.g., urban sprawl, land use, walkability, park area, recreation spaces; examined at national, province or neighbourhood level) and adult obesity prevalence (9). Other cross-sectional studies not part of the systematic review (9) have reported similar findings. A cross-sectional study reported a negative association between physical activity outlet density (per 1000 residents, availability of sport facilities and recreational facilities such as swimming pools, skating rinks) and obesity prevalence (county level, 3106 counties) in the United States (10). Similarly, a five-year prospective cohort study from the United States observed an inverse association between physical activity outlet density (per 1000 people, availability of recreation, and fitness centres) and county-level (3,060 counties) adult obesity prevalence, obesity increased by 5.1 percentage points (11). Likewise, a cross-sectional study undertaken in Sao Paulo, Brazil reported an inverse association between physical activity outlet density (per 1000 residents, availability of parks and other physical activity outlets such as gyms) and municipality-level obesity prevalence (31 sub-municipalities) (12). In summary, the current literature indicates an inverse relationship between availability of physical activity opportunities and obesity prevalence.

The relationship between availability of physical activity opportunities and obesity prevalence is underexamined within the New Zealand setting. Only one cross-sectional study from New Zealand measuring green space reported a non-significant association between neighbourhood-level green space (e.g., availability of parks, beaches and fields, for 1009 census area units) and adult obesity prevalence (as reported in the New Zealand Health Survey 2006/07) (13). Obesity prevalence within this study was not segregated as per Māori New Zealanders and European New Zealanders. This is important as health disparities and disease burden is considerable higher among Māori New Zealanders than their European counterparts (14). Therefore, investigation to understand the association between physical activity opportunities and obesity prevalence specifically within the Māori New Zealanders and European New Zealanders is warranted. Identifying physical activity opportunities supports understanding of possible options the community has in order to enhance their physical activity and in turn maintain a healthy weight status (9). This is crucial for the development and implementation of public health obesity prevention strategies (9). This study therefore aims to examine the association between obesity prevalence and physical activity opportunities defined as availability of physical activity outlets (actual count), and physical activity intensity opportunities (using METs as proxy indicator) in New Zealand.

Methods

Data for this cross-sectional study was collected from May 2004-March 2006 in Waikato and lakes district as a part of Te Wai o Rona: Diabetes Prevention Strategy (8, 15, 16). Waikato and Bay of Plenty Ethics Committees provided ethics clearance. In total, 53 (two urban and 51 rural) geographical locations/clusters were studied (Supplement Figure 1, 2).

Availability of physical activity outlets: The number (actual count) of physical activity outlets in each geographic cluster was undertaken. Physical activity outlets were defined as facilities or programs (fitness centers, walkways, badminton stadium, clubs, etc.) responsible for physical activity of adults. We excluded all outlets related to children (<18 years). Mapping of the physical activity outlets was undertaken by a mesh block approach with reference to the Waikato and Lakes District Councils' databases and the online New Zealand Business Directory database (8, 15, 16). The mapping list was further strengthened by cross-checking it with resident-defined (Māori community health workers) neighborhood boundaries (8, 15, 16). All the data was gathered by researchers physically visiting the outlets in all the clusters.

Mean proxy physical activity intensity opportunities: Physical activity opportunities offered by each geographic cluster was assessed using METs (Metabolic Equivalent of Task) as a proxy indicator (17). One metabolic equivalent (work metabolic rate divided by resting metabolic rate) is defined as one Kcal/kg/hour (17). Each physical activity outlet was assigned a proxy MET score based on the principal physical activity conducted at the outlet. For example, a venue designed for swimming had a proxy METs score of six. METs value to measure physical intensity opportunities was obtained from an adult compendium of physical activities guide (17). METs value assigned to physical activity outlets situated in one cluster was averaged to get a unified MET score for the geographic location. Mean proxy physical activity intensity opportunities were also treated as categorical variable by dividing clusters in to two groups. One comprised of clusters having less than mean METs score (<5.12 METs per cluster) and other included having more than or equal to mean METs score (≥5.12 METs per cluster).

Obesity prevalence: Obesity prevalence data was calculated for the participants residing in the 53 (two urban and 51 rural) geographical locations/clusters and who had agreed to participate in the Te Wai o Rona: Diabetes Prevention Strategy (8, 15, 16). Details of the data collection for Te Wai o Rona: Diabetes Prevention Strategy has been previously reported (8, 15, 16). In brief, residents of the Waikato, and the tribal area of Ngāti TuWharetoa in the neighbouring Lakes were invited to participate via media adverts, local general physicians, work offices and through personal and family contacts. Mean BMI for men 33.1±6.7 kg/m^2 and for women was 32.9±7.8 kg/m^2 (8, 15, 16). Height (without shoes) and weight (in light clothing and without shoes) of the invited participants were measured by stadiometer (to the nearest 0.5 cm) and calibrated weighing scale (Wedderburn TI-BWB800 Personal scales, measured to nearest 0.1kg), respectively. BMI cut-offs for general population (≥30.0 kg/m2) and for Māori and Pacific Island populations (≥32.0 kg/m2) was used to calculate obesity prevalence (18). Obesity BMI cut-offs for Māori and Pacific Islander adults are adjusted to 32kg/m2 as they have lower body fat percentages than Europeans with similar BMI's (18).

Covariates: Median income level (above median income (≥$24,400.01) vs below median income (≤$24,400.00)) and type of location (rural vs urban) was considered as covariates. Data for median income and type of location was obtained from 2006 New Zealand census of Population and Dwelling (19).

Data analysis

The number of physical activity outlets available and proxy mean physical activity intensity opportunities (assessed using METs) were independent variables. Obesity prevalence was the dependant variable (assessed using BMI cut-offs for the general population (≥30.0 kg/m^2) and for the Māori population (≥32.0 kg/m^2). The type of location (rural vs urban) and median income level (above median income (≥$24,400.01) vs below median income (≤$24,400.00)) were considered covariates. Parametric tests were employed to analyse the data. Descriptive statistics for categorical and continuous variables are reported as means with standard deviations or percentages (frequencies), as appropriate. Pearson's correlation was used to report bivariate analysis between the independent continuous variables (mean availability of physical activity outlets per cluster and mean METs proxy indicator available per cluster) and dependant variable (obesity prevalence). Independent samples t-test was used to report bivariate analysis between categorical independent variable (METs proxy indicator, <5.12 METs vs ≥5.12 METs per cluster) and dependant variable (obesity prevalence). Associations significant (p<0.05) at a bivariate level were further investigated by hierarchal linear regression. Covariates (type of location and median income level) were entered in the first block and independent variables (number of physical activity outlets available and proxy mean physical activity intensity opportunities) in the second block. With regard to multivariate outliers and influential data points, all cases had Mahalanobis values below 25 and Cook's D values below one. Therefore, all cases were included in the final analyses (20). No concerns regarding multicollinearity were noted (variance inflation factor for all variables below 10) (20). Moderation effect of any covariate was tested by using PROCESS version 3.4 by Andrew F. Hayes (21). The analyses were two tailed and the significance level was set at 5%. All the data were analysed using SPSS version 25 (SPSS Inc., Chicago, USA).

Results

Table 1 describes the cluster level characteristics for the number of physical activity outlets availability, mean physical activity intensity opportunities in METs (METs proxy indicator) and percent obesity prevalence as per BMI cut-offs recommended for the general and Māori population. Clusters with no physical activity outlets (n=26) were not considered for estimating METs proxy indicator.

Pearson's correlation reported that there was no significant association between mean availability of physical activity outlets per cluster and obesity prevalence using general (r=-0.04, p=0.80) and Māori (r=-0.02, p=0.88) BMI cut-offs. Similarly, no significant association was observed between mean physical activity intensity opportunities in METs available per cluster (METs proxy indicator) and obesity prevalence using general (r=0.47, p=0.82) and Māori (r=-0.32, p=0.88) BMI cut-offs.

Independent samples t-test reported no significant difference in obesity prevalence using general BMI cut-offs between clusters with proxy METs <5.12 (n=15) and proxy METs ≥5.12 (n=10), 64.00±0.17 vs 56.40±0.08% obesity prevalence, t(21.81)=1.45, p=0.16. However, a significant difference was observed in obesity prevalence using Māori BMI cut-offs between clusters with proxy METs <5.12 (n=15) and proxy METs ≥5.12 (n=10), 56.20±0.22 vs 43.30±0.07% obesity prevalence, t(17.77)=1.45, p=0.03.

Significant association between obesity prevalence using Māori BMI cut-offs and METs proxy indicator (<5.12 per cluster vs ≥5.12 per cluster) was further examined using multivariate hierarchical linear regression (Table 2). After controlling for income (above vs below median income) and type of locality (rural vs urban) a significant inverse association was observed between METs proxy indicator and obesity prevalence using Māori BMI cut-offs (β=-0.421, p=0.03).

Further investigation highlighted the moderating role of income (Table 2, Figure 1). When income was low (below the median, ≤ NZ $24,400), there was a significant inverse relationship between mean METs proxy indicator and obesity prevalence using Māori BMI cut-offs. Income (Below median)*mean METs proxy indicator, *b*=-0.4661, 95% CI (-0.6054, -0.3268), t=-7.0047, p<0.001, $R^2 = 0.12$, *F* (1.00, 19.00)=15.75, p=0.0008.

Discussion

This study examines the association between the number of physical activity outlets availability and proxy physical activity intensity opportunities in METs (METs proxy indicator) with percent obesity prevalence as BMI cut-offs recommended for the general and the Māori population. The number of physical activity outlets availability was not significantly associated with obesity prevalence (for both the general and the Māori population). There was a significant inverse association between proxy physical activity intensity opportunities in METs (METs used as proxy indicator) and percent obesity prevalence measured using the Māori BMI cut-offs. Furthermore, low income (≤ NZ $24,400) moderated the association between low physical activity intensity opportunities and high obesity prevalence (using Māori BMI cut-offs).

With respect to the relationship between percent obesity prevalence (by Māori BMI cut offs) and number of physical activity outlets availability, the result of our study contradicts with two cross-sectional and one prospective cohort study from the United States. Results reported that county level (n=3106, 3109, 3104) obesity prevalence (BMI >30 kg/m^2) was inversely associated with the availability of physical activity outlets (per 1000 residents, defined as fitness facilities and programs, sports and health clubs, swimming and tennis facilities, skating rinks) (10, 11, 22). Difference in the method of measuring availability of physical activity outlets (density vs actual counts undertaken in the current study) (10, 11, 22) and different geographical location (United States vs current study: New Zealand) might explain the discrepancy in the result. New Zealand, being an island nation, has the benefit of a large coastline. In a national level, cross-sectional study in New Zealand, access to public beaches was studied by Geographic Information Systems (GIS) in 38,350 neighbourhoods. In total, 75% of the neighbourhoods had easy access to beaches by a car (31.8 minutes) (23). Accessibility to freely available physical activity promoting natural resources such as beaches may have partly contributed to the insignificant relationship between availability of physical activity outlets and obesity prevalence.

Results highlighted that low income (≤ NZ $24,400) moderated the association between low physical activity intensity opportunities and high obesity prevalence (using Māori BMI cut-offs). There is a dearth of literature examining the moderating role of income on physical activity opportunities and obesity prevalence. The role of physical activity and income are generally examined as independent variables in the literature rather than study its complex interrelationship with obesity. In line with the current study which observed an inverse association between proxy physical activity intensity opportunities and obesity prevalence, a national cross-sectional dataset (NHANES III, n=4889) reported that obesity (BMI≥30 kg/m^2) was approximately 50% lower in American adults who engage in regular moderate to vigorous (3 to >6 METs) leisure-time physical activity compared to their counterparts who did not engage in any leisure-time physical activity (24). Therefore, the literature has reported an inverse association between physical activity as an independent variable and obesity prevalence. However, such evidence needs to be extrapolated with caution due to inter-country differences (United States vs current study: New Zealand) and individual-level METs were used to record leisure-time physical activity (whereas the current study used proxy METs, assigning each physical activity outlet a MET). Similarly, literature has examined the relationship between income as an independent variable and obesity. A meta-analysis of 14 cross-sectional and longitudinal studies, conducted in developed (United States) and upper-middle-income (Brazil) countries demonstrated that participants with lower socioeconomic status had higher BMI than their counterparts (lowest vs highest socio-economic category, mean BMI difference: 0.65, 95% CI: 0.59, 0.71) (25). Therefore, an inverse association was observed in the literature between income as an independent variable and obesity prevalence. Our findings uniquely identified the association between physical activity intensity opportunities (using METs as proxy indicator) and obesity prevalence moderated by income specifically among the Māori population. This supports physical activity interventions in New Zealand which are tailored for the Māori population such as 'Korikori A Iwi' (free nutrition and physical activity community initiative) as an initiative to improve health and wellbeing (26).

To our knowledge this is the first study in New Zealand to explore the association between availability of physical activity outlets, proxy physical activity intensity opportunities and obesity prevalence. More than 95% of our geographical locations were rural, which is a strength of this paper. A large systematic review of 63 predominantly cross-sectional studies from the United States examining the built environment (physical activity, food and land use and transportation environment) and obesity prevalence, highlighted that only seven studies were conducted in a rural setting (27). We used both the Māori (≥32.0 kg/m2) and general (≥30.0 kg/m2) BMI cut-offs to study obesity prevalence which reflects sensitivity of the analysis undertaken (8, 28). Since there is no set recommended protocol to map physical activity outlets, we undertook a data triangulation approach and sourced comprehensive information on physical activity outlets from those commercially available, the local council, and crosschecked the data with expert Māori community health worker in order to reduce errors such as low sensitivity and low specificity (8, 29). There is a possibility that unregistered outlets (e.g., informal walking groups) might have been missed. It is important to note that availability of physical activity outlets and physical activity intensity opportunities (METs as proxy indicator) are only two of the multi-level complex determinants of obesity (e.g., age, gender, dietary patterns, food security, socio-economic status, cultural background, etc). Since our present study is cross-sectional in nature, it cannot ascertain causality. We were unable to analyse ethnicity and occupation related census data due to resource constraints. However, these factors can be explored in future studies.

Our study highlighted that low income moderated the association between low proxy physical activity intensity opportunities and high obesity prevalence in Māori. In low-income Māori groups, encouraging culturally appropriate physical activity may therefore support public health interventions addressing obesity such as the 'Korikori A Iwi' program (26). Since availability of physical activity outlets was not significantly associated with obesity prevalence, future research could investigate the categorisation of physical activity outlets such as paid vs unpaid outlets (fitness centres vs parks), natural resources vs man-made resources (nature reserves vs stadiums) or indoor outlets vs outdoor outlets (table tennis courts vs rugby fields).

Acknowledgments:

We thank the investigator group, Kaitiaki, Māori Community Health Workers, Te Wai o Rona: Diabetes Prevention Strategy project team, and local health service staff for their varied contributions to the study. We thank Mr. Konrad Uebel for helping us in visual mapping of the data. Funding was provided by Health Research Council, Waikato District Health Board, Lakes District Health Board, Ministry of Health, Sport and Recreation New Zealand, Southern Trust, Waikato Local Diabetes Team and Merck, Sharp and Dohme. Support in-kind was provided by Roche Diagnostics, Pathlab, Medlab, University of Auckland, Auckland University of Technology, Wintec, Te Hotu Manawa Māori, Eggs Inc, Vodafone, Rivermill Bakers and Sun Fruit.

References

1. World Health Organization. Obesity and overweight 2020. Accessed 2021 Sept 09. URL: https://www.who.int/news-room/fact-sheets/detail/obesity-and-overweight.
2. Ministry of Health. Annual Update of Key Results 2019/20: New Zealand Health Survey. Wellington: Ministry of Health, 2020.
3. Atkinson J, Salmond C, P C. NZDep2013 Index of Deprivation. Wellington: University of Otago, 2014.
4. Guh DP, Zhang W, Bansback N, Amarsi Z, Birmingham CL, Anis AH. The incidence of co-morbidities related to obesity and overweight: a systematic review and meta-analysis. BMC public health. 2009;9(1):1-20.
5. Theodore R, McLean R, TeMorenga L. Challenges to addressing obesity for Māori in Aotearoa/New Zealand. Aust N Z J Public Health. 2015;39(6):509-12.
6. Lal A, Moodie M, Ashton T, Siahpush M, Swinburn B. Health care and lost productivity costs of overweight and obesity in New Zealand. Aust N Z J Public Health. 2012;36(6):550-6.
7. Swinburn B, Egger G, Raza F. Dissecting obesogenic environments: the development and application of a framework for identifying and prioritizing environmental interventions for obesity. Prev Med. 1999;29(6):563-70.
8. Jani R, Rush E, Crook N, Simmons D. Availability and price of healthier food choices and association with obesity prevalence in New Zealand Maori. Asia Pac J Clin Nutr. 2018;27(6):1357-65.
9. Mackenbach JD, Rutter H, Compernolle S, Glonti K, Oppert J-M, Charreire H, et al. Obesogenic environments: a systematic review of the association between the physical environment and adult weight status, the SPOTLIGHT project. BMC public health. 2014;14(1):1-15.
10. Pitts SBJ, Edwards MB, Moore JB, Shores KA, DuBose KD, McGranahan D. Obesity is inversely associated with natural amenities and recreation facilities per capita. J Phys Act Health. 2013;10(7):1032-8.
11. Myers CA, Slack T, Martin CK, Broyles ST, Heymsfield SB. Change in obesity prevalence across the United States is influenced by recreational and healthcare contexts, food environments, and Hispanic populations. PloS one. 2016;11(2):e0148394.
12. Jaime PC, Duran AC, Sarti FM, Lock K. Investigating environmental determinants of diet, physical activity, and overweight among adults in Sao Paulo, Brazil. J Urban Health. 2011;88(3):567-81.
13. Richardson EA, Pearce J, Mitchell R, Kingham S. Role of physical activity in the relationship between urban green space and health. Public health. 2013;127(4):318-24.
14. Yu D, Zhao Z, Osuagwu UL, Pickering K, Baker J, Cutfield R, et al. Ethnic differences in mortality and hospital admission rates between Māori, Pacific, and European New Zealanders with type 2 diabetes between 1994 and 2018: a retrospective, population-based, longitudinal cohort study. Lancet Glob Health. 2021;9(2):e209-e17.
15. Simmons D, Rush E, Crook N, Team TWoRDPS. Development and piloting of a community health worker-based intervention for the prevention of diabetes among New Zealand Maori in Te Wai o Rona: Diabetes Prevention Strategy. Public Health Nutr. 2008;11(12):1318-25.
16. Simmons D, Rush E, Crook N. Prevalence of undiagnosed diabetes, impaired glucose tolerance, and impaired fasting glucose among Māori in Te Wai o Rona: Diabetes Prevention Strategy. N Z Med J. 2009;122(1288):18-27.
17. Ainsworth BE, Haskell WL, Whitt MC, Irwin ML, Swartz AM, Strath SJ, et al. Compendium of physical activities: an update of activity codes and MET intensities. Med Sci Sports Exerc. 2000;32(9; SUPP/1):S498-S504.

18. Dancause KN, Vilar M, DeHuff C, Wilson M, Soloway LE, Chan C, et al. Relationships between body size and percent body fat among Melanesians in Vanuatu. Asia Pac J Clin Nutr. 2010;19(3):425-31.
19. Statistics New Zealand. 2006 Census of Population and Dwellings. Accessed 2021 Sept 09. URL: https://cdm20045.contentdm.oclc.org/digital/collection/p20045coll20/search.
20. Field A. Discovering statistics using IBM SPSS statistics. Thousand Oaks, CA: Sage, 2013.
21. Hayes AF. Introduction to mediation, moderation, and conditional process analysis: A regression-based approach. Seventh Avenue, NY: Guilford publications, 2017.
22. Slack T, Myers CA, Martin CK, Heymsfield SB. The geographic concentration of US adult obesity prevalence and associated social, economic, and environmental factors. Obesity. 2014;22(3):868-74.
23. Witten K, Hiscock R, Pearce J, Blakely T. Neighbourhood access to open spaces and the physical activity of residents: a national study. Prev Med. 2008;47(3):299-303.
24. King GA, Fitzhugh E, Bassett Jr D, McLaughlin J, Strath SJ, Swartz AM, et al. Relationship of leisure-time physical activity and occupational activity to the prevalence of obesity. Int J Obes. 2001;25(5):606-12.
25. Newton S, Braithwaite D, Akinyemiju TF. Socio-economic status over the life course and obesity: Systematic review and meta-analysis. PloS one. 2017;12(5):e0177151.
26. Te Hiku Hauora. Korikori A Iwi Nutrition and Activity for Community. Accessed 2021 Sept 09. URL: https://www.tehikuhauora.nz/tane-wahine-adult/korikori-a-iwi-nutrition-and-activity-for-community/.
27. Feng J, Glass TA, Curriero FC, Stewart WF, Schwartz BS. The built environment and obesity: a systematic review of the epidemiologic evidence. Health Place. 2010;16(2):175-90.
28. Fischhoff B, Slovic P, Lichtenstein S. Subjective sensitivity analysis. Organ Behav Hum Perform. 1979;23(3):339-59.
29. Cobb LK, Appel LJ, Franco M, Jones-Smith JC, Nur A, Anderson CA. The relationship of the local food environment with obesity: a systematic review of methods, study quality, and results. Obesity. 2015;23(7):1331-44.

Table 1: Descriptive characteristics of the study variables

Variables	Mean±SD OR n (%)
Independent variables	
Mean availability of physical activity outlets per cluster (n=53)	15.47±35.27
Mean METs proxy indicator available per cluster (n=27)	5.12±1.49
METs proxy indicator (<5.12 per cluster) *	16 (59.3)
Dependent variables	
Obesity percent prevalence (general BMI cut-offs ≥30.0 kg/m^2) (n=50)	0.60±0.18
Obesity percent prevalence (Māori BMI cut-offs ≥32 kg/m^2) (n=50)	0.49±0.21
Covariates	
Income (Below median)**	30 (62.5)
Type of locality (Rural)***	51 (96.2)

*Mean physical intensity opportunities in METs (METs proxy indicator <5.12 per cluster vs ≥5.12 per cluster)

**Median income (above median income NZ$: ≥$24,400.01 vs below median income: ≤$24,400.00)

***Type of locality (Rural vs Urban)

Table 2: Hierarchical linear regression between obesity prevalence using Māori BMI cut-offs and METs proxy indicator (n= 24)

Variables	β value	p value
Hierarchical linear regression*		
Income (Below median)	- 0.517	0.01
Type of locality (Rural)	0.139	0.45
METs proxy indicator (<5.12 per cluster)	- 0.421	0.03
Δ R^2 = 0.174; Δ F (1, 20) = 5.662, p= 0.03. R^2 (R^2 Adj) 0.384 (0.292); F (20,23) = 4.159, p= 0.02		
Moderation	**t value**	**p value**
Income (Below median)	-5.808	<0.001
Type of locality (Rural)	-0.305	0.76
Mean METs proxy indicator	-3.606	0.002
R^2 = 0.71, *F* (4.00, 19.00) = 16.14, p<0.001		

*Hierarchical linear regression: Covariates at step 1: Income (Below median), Type of locality (Rural). Step 2: METs proxy indicator (<5.12 per cluster)

Dependant variable= Obesity prevalence using Māori BMI cut-offs

Note: Moderation analysis using PROCESS version 3.4 by Andrew F. Hayes in SPSS version 25 (SPSS Inc., Chicago, USA).

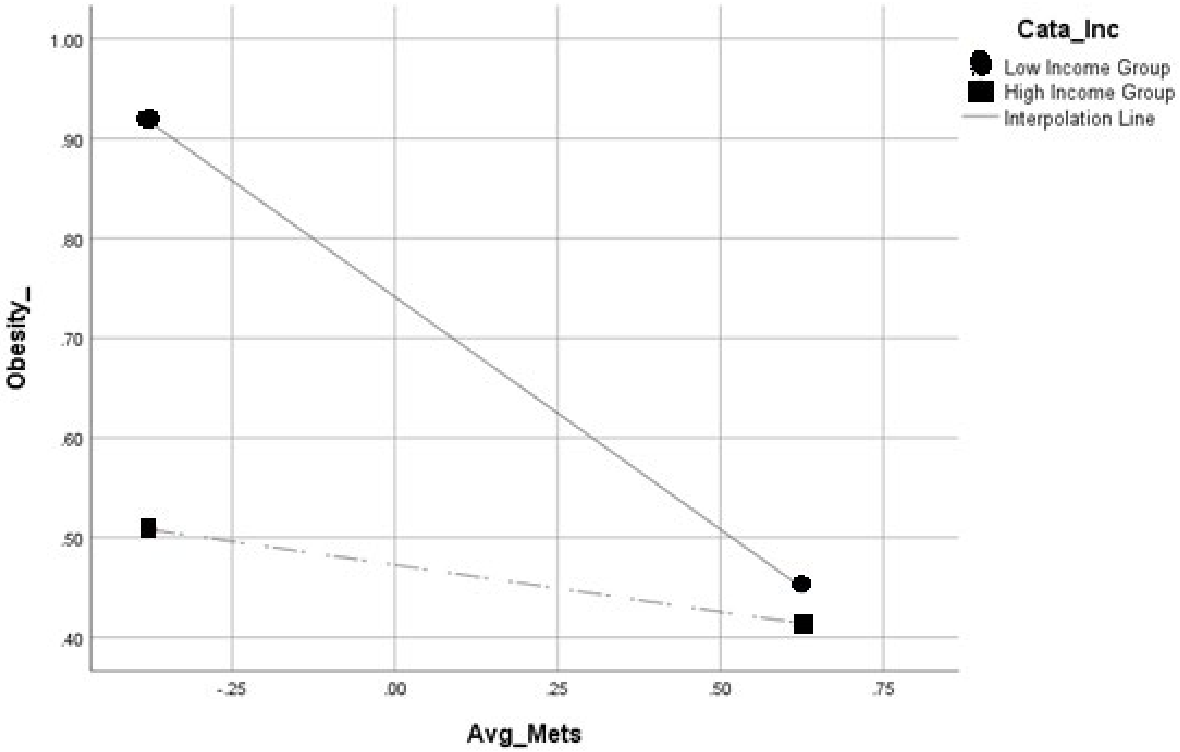
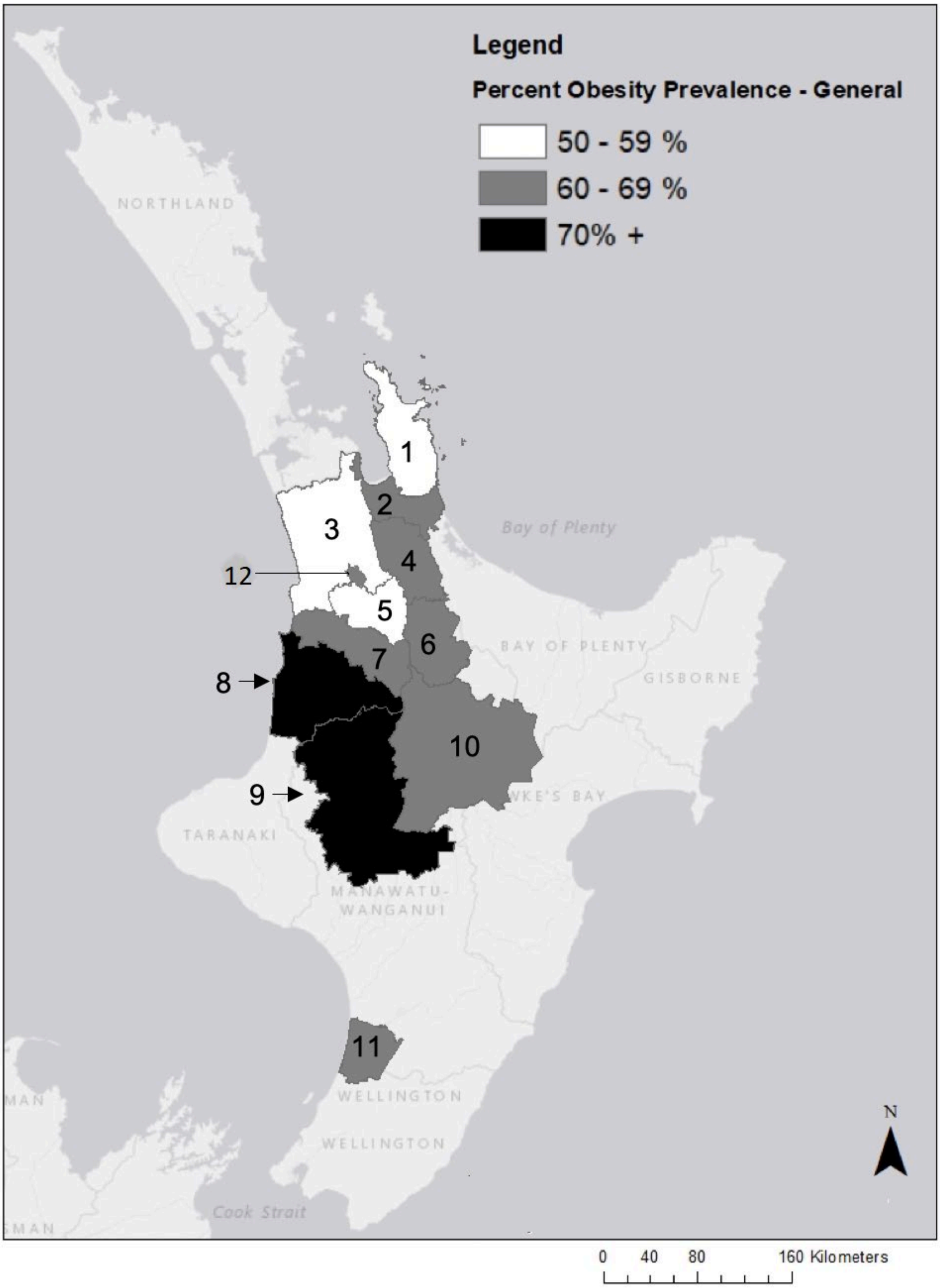


Figure 1: Simple Slopes equations of the regression of mean METs proxy indicator on obesity prevalence using Māori BMI cut-offs at two levels of income (above median income NZ$: ≥$24,400.01 vs below median income: ≤$24,400.00).

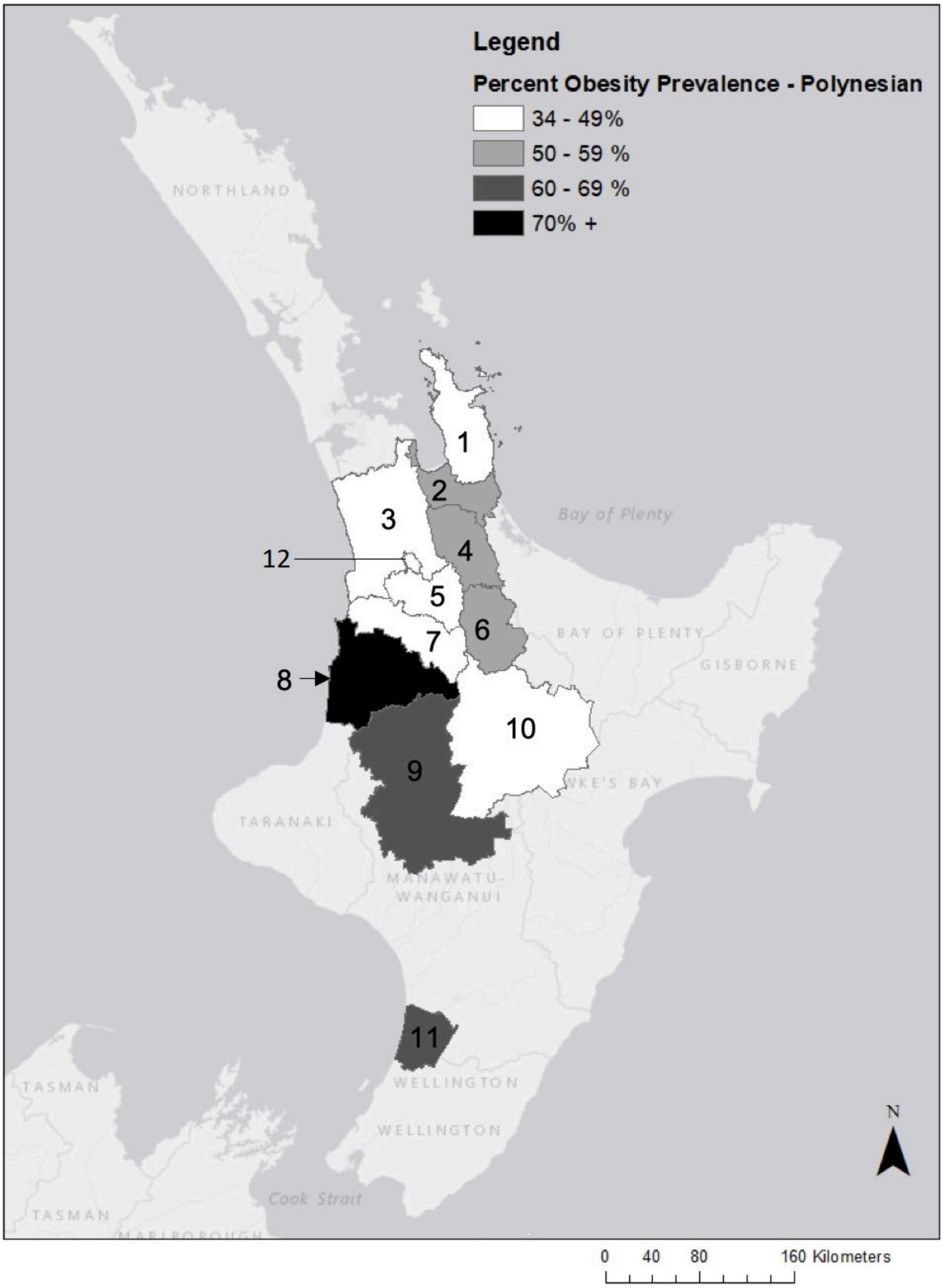


Supplement Figure 1: Details of obesity prevelance per cluster as per general BMI cut-offs ≥ 30.0 kg/m^2

Notes:

1. District (Mean obesity prevalence) – Thames-Coromandel district (51%) includes whitianga – (obesity prevalence- 71%), Coromandel (obesity prevalence -50%), Wairakei_Aratiatia (obesity prevalence -54%) , Tairua (obesity prevalence -39%), Thames (obesity prevalence -38%), Pauanuitairua (obesity prevalence -54%)

2. District (Mean obesity prevalence) -Hauraki District (66%) Kerpehi– (obesity prevalence- 60%), Ngatea kaihere (obesity prevalence - 64%), Turua (obesity prevalence - 50%), Paeroa (obesity prevalence - 93 %), Waihi (obesity prevalence -63 %)
3. District (Mean obesity prevalence) - Waikato District (50%) includes Raglan– (obesity prevalence- 14 %), Te Kauwhata (obesity prevalence - 58%), Meremere (obesity prevalence - 50%) , Huntly (obesity prevalence -72 %), Te Kowhai (obesity prevalence -61 %), Ngaruawahia (obesity prevalence -67 %), Te_uku (obesity prevalence -61 %), Matangi (obesity prevalence -25 %), Taupiri (obesity prevalence - 25%), Eureka (obesity prevalence - 58%), Gordonton (obesity prevalence - 29%), Maramarua (obesity prevalence -83 %), Whatawhata (obesity prevalence -50 %)
4. District (Mean obesity prevalence) - Matamata-Piako District (63%) includes Waitoa– (obesity prevalence- 100 %), Waharoa– (obesity prevalence- 50 %), Te poi– (obesity prevalence- 74 %), Matamata– (obesity prevalence- 57 %), Te_aroha– (obesity prevalence- 52 %), Hinuera– (obesity prevalence- 44 %)
5. District (Mean obesity prevalence) - Waipa District (58%) includes Cambridge– (obesity prevalence- 63 %), Cambridge– (obesity prevalence- 51 %), Lake ngaroto– (obesity prevalence- 68 %), Te_Awamutu– (obesity prevalence- 50 %), Karapiro– (obesity prevalence- 62 %), kihikihi– (obesity prevalence- 53 %)
6. District (Mean obesity prevalence) - South Waikato District (64%) includes Tirau– (obesity prevalence- 66 %), includes Lichfield– (obesity prevalence- 58 %), includes Waitomo– (obesity prevalence- 68 %)
7. District (Mean obesity prevalence) - Ōtorohanga District (64%) includes Mangakino– (obesity prevalence- 50 %), Turangi– (obesity prevalence- 100 %), Otorohonga_te_Kuiti_piopio– (obesity prevalence- 55%)
8. District (Mean obesity prevalence) - Waitomo District (82%) includes Tagaroa_marakopa– (obesity prevalence- 100 %), Putaruru– (obesity prevalence- 63 %),
9. District (Mean obesity prevalence) - Ruapehu District (74%) includes Taumarunui– (obesity prevalence- 67 %), Ohura– (obesity prevalence- 56 %), National park– (obesity prevalence- 100 %),
10. District (Mean obesity prevalence) - Taupo District (64%) includes Taupo – (obesity prevalence- 64 %)
11. District (Mean obesity prevalence) - Horowhenua District (67%) includes Marotiri– (obesity prevalence- 67 %)
12. District (Mean obesity prevalence) - Hamilton District (62%) includes Hamilton city– (obesity prevalence- 62 %)



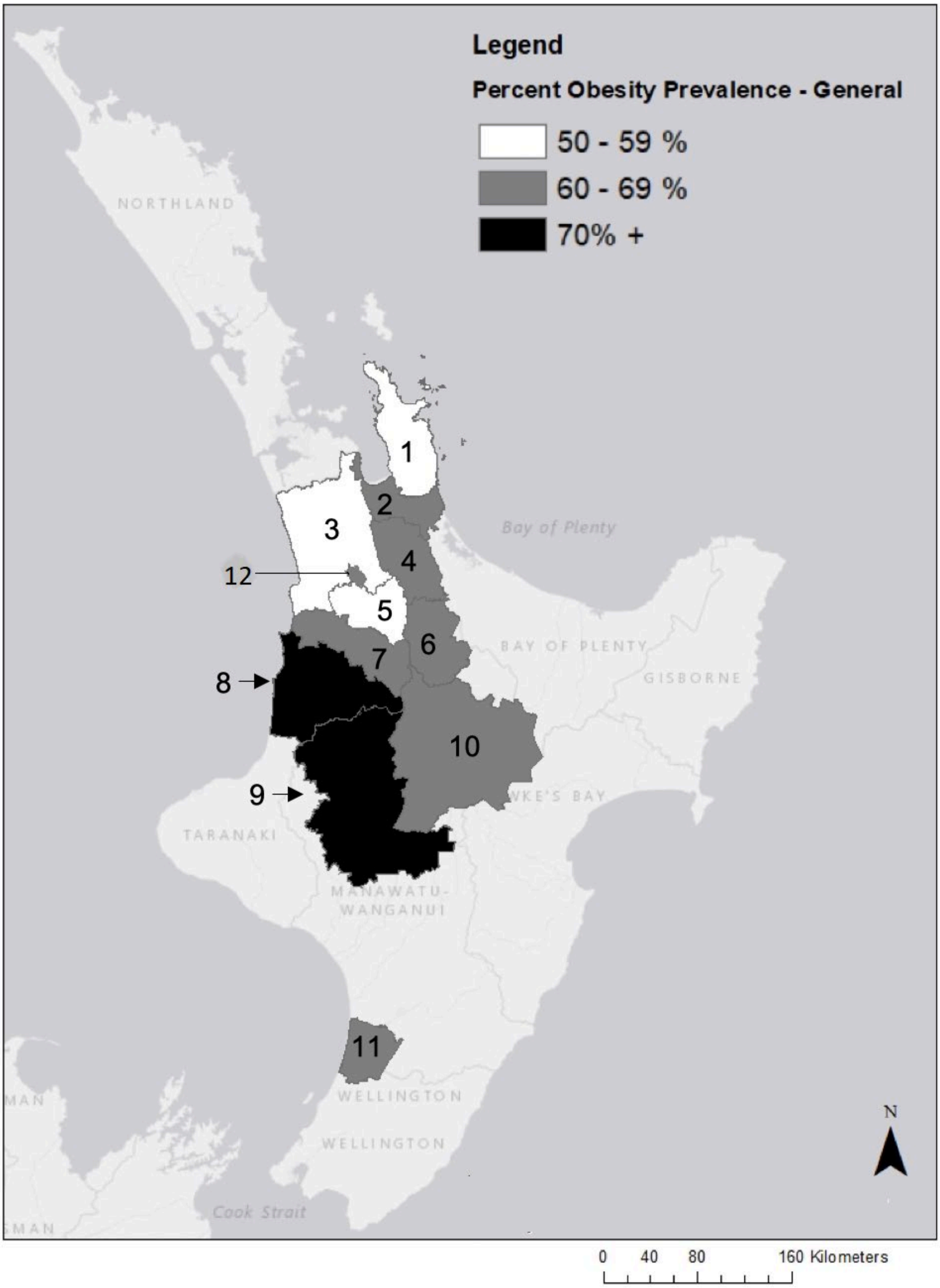
Supplement Figure 2: Details of obesity prevelance per cluster as per Māori (Polynesian)BMI cut-offs ≥ 30.0 kg/m^2

Notes:

1. District (Mean obesity prevalence) – Thames-Coromandel district (34%) includes whitianga – (obesity prevalence- 58%), Coromandel (obesity prevalence -34%), Wairakei_Aratiatia (obesity prevalence - 39%) , Tairua (obesity prevalence -30%), Pauanuitairua (obesity prevalence -46%)

2. District (Mean obesity prevalence) -Hauraki District (51%) includes Kerpehi – (obesity prevalence- 49%), Ngatea kaihere (obesity prevalence - 55%), Turua (obesity prevalence - 33%), Paeroa (obesity prevalence - 64 %), Waihi (obesity prevalence -53 %)
3. District (Mean obesity prevalence) - Waikato District (42%) includes, Te Kauwhata (obesity prevalence - 46%), Meremere (obesity prevalence - 38%) , Huntly (obesity prevalence -56 %), Te Kowhai (obesity prevalence -49 %), Ngaruawahia (obesity prevalence -67 %), Te_uku (obesity prevalence -51 %), Matangi (obesity prevalence -25%), Eureka (obesity prevalence - 46%), Gordonton (obesity prevalence - 29%), Maramarua (obesity prevalence -83 %), Whatawhata (obesity prevalence -50 %)
4. District (Mean obesity prevalence) - Matamata-Piako District (63%) includes Waitoa – (obesity prevalence- 100 %), Waharoa – (obesity prevalence- 50 %), Te poi – (obesity prevalence- 61 %), Matamata – (obesity prevalence- 57 %), Te_aroha – (obesity prevalence- 39 %), Hinuera – (obesity prevalence- 41 %)
5. District (Mean obesity prevalence) - Waipa District (47%) includes Cambridge – (obesity prevalence- 63 %), Cambridge – (obesity prevalence- 42 %), Lake ngaroto – (obesity prevalence- 53 %), Te_Awamutu – (obesity prevalence- 25 %), Karapiro – (obesity prevalence- 51 %), kihikihi – (obesity prevalence- 45 %)
6. District (Mean obesity prevalence) - South Waikato District (50%) includes Tirau – (obesity prevalence- 50 %), includes Lichfield – (obesity prevalence- 53 %), includes Waitomo – (obesity prevalence- 47 %)
7. District (Mean obesity prevalence) - Ōtorohanga District (45%) includes Mangakino – (obesity prevalence- 50 %), Turangi – (obesity prevalence- 50 %), Otorohonga_te_Kuiti_piopio – (obesity prevalence- 45%)
8. District (Mean obesity prevalence) - Waitomo District (82%) includes Tagaroa_marakopa – (obesity prevalence- 100 %), Putaruru – (obesity prevalence- 63 %),
9. District (Mean obesity prevalence) - Ruapehu District (65%) includes Taumarunui – (obesity prevalence- 50 %), Ohura – (obesity prevalence- 46 %), National park – (obesity prevalence- 100 %),
10. District (Mean obesity prevalence) - Taupo District (43%) includes Taupo – (obesity prevalence- 43 %)
11. District (Mean obesity prevalence) - Horowhenua District (67%) includes Marotiri – (obesity prevalence- 67 %)
12. District (Mean obesity prevalence) - Hamilton District (49%) includes Hamilton city – (obesity prevalence- 49 %)

Figure 1: Details of obesity prevelance per cluster as per general BMI cut offs $\geq$ 30.0 kg/m^2



1. District (Mean obesity prevalence) – Thames-Coromandel district (51%) includes whitianga – (obesity prevalence- 71%), Coromandel (obesity prevalence -50%), Wairakei_Aratiatia (obesity prevalence -54%) , Tairua (obesity prevalence -39%), Thames (obesity prevalence -38%), Pauanuitairua (obesity prevalence -54%)

2. District (Mean obesity prevalence) -Hauraki District (66%) Kerpehi– (obesity prevalence- 60%), Ngatea kaihere (obesity prevalence - 64%), Turua (obesity prevalence - 50%), Paeroa (obesity prevalence - 93 %), Waihi (obesity prevalence -63 %)

3. District (Mean obesity prevalence) - Waikato District (50%) includes Raglan– (obesity prevalence- 14 %), Te Kauwhata (obesity prevalence - 58%), Meremere (obesity prevalence - 50%) , Huntly (obesity prevalence -72 %), Te Kowhai (obesity prevalence - 61 %), Ngaruawahia (obesity prevalence -67 %), Te_uku (obesity prevalence -61 %), Matangi (obesity prevalence -25 %), Taupiri (obesity prevalence - 25%), Eureka (obesity prevalence - 58%), Gordonton (obesity prevalence - 29%), Maramarua (obesity prevalence -83 %), Whatawhata (obesity prevalence -50 %)

4. District (Mean obesity prevalence) - Matamata-Piako District (63%) includes Waitoa– (obesity prevalence- 100 %), Waharoa– (obesity prevalence- 50 %), Te poi– (obesity prevalence- 74 %), Matamata– (obesity prevalence- 57 %), Te_aroha– (obesity prevalence- 52 %), Hinuera– (obesity prevalence- 44 %)

5. District (Mean obesity prevalence) - Waipa District (58%) includes Cambridge– (obesity prevalence- 63 %), Cambridge– (obesity prevalence- 51 %), Lake ngaroto– (obesity prevalence- 68 %), Te_Awamutu– (obesity prevalence- 50 %), Karapiro– (obesity prevalence- 62 %), kihikihi– (obesity prevalence- 53 %)

6. District (Mean obesity prevalence) - South Waikato District (64%) includes Tirau– (obesity prevalence- 66 %), includes Lichfield– (obesity prevalence- 58 %), includes Waitomo– (obesity prevalence- 68 %)

7. District (Mean obesity prevalence) - Ōtorohanga District (64%) includes Mangakino– (obesity prevalence- 50 %), Turangi– (obesity prevalence- 100 %), Otorohonga_te_Kuiti_piopio– (obesity prevalence- 55%)

8. District (Mean obesity prevalence) - Waitomo District (82%) includes Tagaroa_marakopa– (obesity prevalence- 100 %), Putaruru– (obesity prevalence- 63 %),

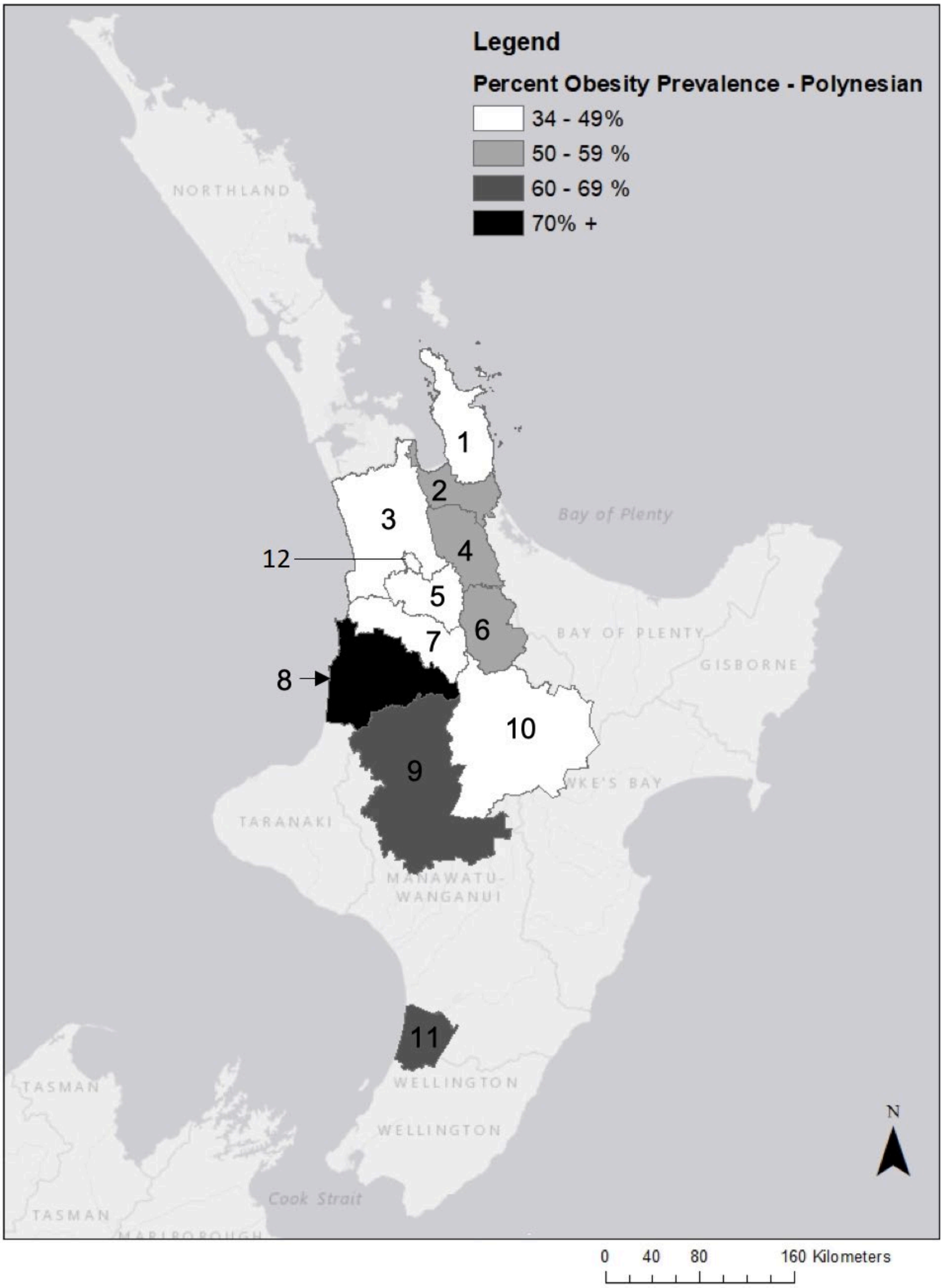
9. District (Mean obesity prevalence) - Ruapehu District (74%) includes Taumarunui– (obesity prevalence- 67 %), Ohura– (obesity prevalence- 56 %), National park– (obesity prevalence- 100 %),

10. District (Mean obesity prevalence) - Taupo District (64%) includes Taupo – (obesity prevalence- 64 %)

11. District (Mean obesity prevalence) - Horowhenua District (67%) includes Marotiri– (obesity prevalence- 67 %)

12. District (Mean obesity prevalence) - Hamilton District (62%) includes Hamilton city– (obesity prevalence- 62 %)

Figure 2: Details of obesity prevelance per cluster as per Māori (Polynesian)BMI cut offs > 30.0 kg/m^2



1. District (Mean obesity prevalence) – Thames-Coromandel district (34%) includes whitianga – (obesity prevalence- 58%), Coromandel (obesity prevalence -34%),

Wairakei_Aratiatia (obesity prevalence - 39%) , Tairua (obesity prevalence -30%), Pauanuitairua (obesity prevalence -46%)

2. District (Mean obesity prevalence) -Hauraki District (51%) includes Kerpehi – (obesity prevalence- 49%), Ngatea kaihere (obesity prevalence - 55%), Turua (obesity prevalence - 33%), Paeroa (obesity prevalence - 64 %), Waihi (obesity prevalence -53 %)

3. District (Mean obesity prevalence) - Waikato District (42%) includes, Te Kauwhata (obesity prevalence - 46%), Meremere (obesity prevalence - 38%) , Huntly (obesity prevalence -56 %), Te Kowhai (obesity prevalence -49 %), Ngaruawahia (obesity prevalence -67 %), Te_uku (obesity prevalence -51 %), Matangi (obesity prevalence - 25%), Eureka (obesity prevalence - 46%), Gordonton (obesity prevalence - 29%), Maramarua (obesity prevalence -83 %), Whatawhata (obesity prevalence -50 %)

4. District (Mean obesity prevalence) - Matamata-Piako District (63%) includes Waitoa – (obesity prevalence- 100 %), Waharoa – (obesity prevalence- 50 %), Te poi – (obesity prevalence- 61 %), Matamata – (obesity prevalence- 57 %), Te_aroha – (obesity prevalence- 39 %), Hinuera – (obesity prevalence- 41 %)

5. District (Mean obesity prevalence) - Waipa District (47%) includes Cambridge – (obesity prevalence- 63 %), Cambridge – (obesity prevalence- 42 %), Lake ngaroto – (obesity prevalence- 53 %), Te_Awamutu – (obesity prevalence- 25 %), Karapiro – (obesity prevalence- 51 %), kihikihi – (obesity prevalence- 45 %)

6. District (Mean obesity prevalence) - South Waikato District (50%) includes Tirau – (obesity prevalence- 50 %), includes Lichfield – (obesity prevalence- 53 %), includes Waitomo – (obesity prevalence- 47 %)

7. District (Mean obesity prevalence) - Ōtorohanga District (45%) includes Mangakino – (obesity prevalence- 50 %), Turangi – (obesity prevalence- 50 %), Otorohonga_te_Kuiti_piopio – (obesity prevalence- 45%)

8. District (Mean obesity prevalence) - Waitomo District (82%) includes Tagaroa_marakopa – (obesity prevalence- 100 %), Putaruru – (obesity prevalence- 63 %),

9. District (Mean obesity prevalence) - Ruapehu District (65%) includes Taumarunui – (obesity prevalence- 50 %), Ohura – (obesity prevalence- 46 %), National park – (obesity prevalence- 100 %),

10. District (Mean obesity prevalence) - Taupo District (43%) includes Taupo – (obesity prevalence- 43 %)

11. District (Mean obesity prevalence) - Horowhenua District (67%) includes Marotiri – (obesity prevalence- 67 %)

12. District (Mean obesity prevalence) - Hamilton District (49%) includes Hamilton city – (obesity prevalence- 49 %)