A spatial analysis of the geographic distribution of musculoskeletal
and general practice healthcare clinics in Auckland, New Zealand

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A thesis submitted in partial fulfilment of the requirements for the degree of
Master of Osteopathy.

Declaration

Name of candidate: Lara Jane Sanders

This Thesis/Dissertation/Research Project entitled “A spatial analysis of the geographic distribution of musculoskeletal and general practice healthcare clinics in Auckland, New Zealand” is submitted in partial fulfilment for the requirements for the Unitec degree of Master of Osteopathy.

CANDIDATE’S DECLARATION

I confirm that:

- This Thesis represents my own work;
- Research for this work has been conducted in accordance with the Unitec Research Ethics Committee Policy and Procedures, and has fulfilled any requirements set for this project by the Unitec Research Ethics Committee.

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Acknowledgements

This project would not have been possible without the assistance of my two research supervisors, Catherine Bacon and Glenn Aguilar. Thank you.

Thank you to my friends and family, especially Gary, for your unwavering support, love and encouragement throughout the completion of this thesis.

Abstract

Background & Aims: Musculoskeletal disorders represent a substantial health burden, both within society and to the general practice workload. Although a number of allied and complementary musculoskeletal healthcare options are available in the primary healthcare system, the geographic distribution of such healthcare clinics may be subject to a number of social and commercial influences that may not take into account the healthcare needs of the population. The dual aims of the study reported in this thesis were to determine the extent to which the geographical distribution of musculoskeletal healthcare clinics varies across urban Auckland, in comparison to general practitioner (GP) clinics, and to determine factors which may be related to variations in the spatial pattern of clinic locations.

Methods: The locations of all physiotherapy, chiropractic, osteopathic, podiatry, acupuncture and GP clinics in urban Auckland were mapped and analysed using a combination of spatial statistical tools. Kernel density, Getis-Ord G_i^* and Local Moran's I statistics were utilised to visualise clinic spatial distributions and patterns. Regression modelling using Ordinary Least Squares and Geographically Weighted Regression statistics was conducted to describe relationships between clinic locations and the urban environment.

Results: Musculoskeletal clinics showed evidence of clustering in central and northern parts of Auckland, with regression analyses highlighting the importance of clinic proximity to major roads and urban centres, and location within areas of higher percentages of European residents and socioeconomic prosperity. GP clinics appeared more evenly distributed across the study area, with areas of higher clinic density particularly in central and southern Auckland.

Conclusion: The results of this study suggest that musculoskeletal clinics may tend to be positioned to capture the commercial advantages of location within urban areas with a high commuter inflow and a population with the financial resources to afford privately funded treatment. These results may help to inform the development of strategies to improve the accessibility of musculoskeletal healthcare services for people living or working in areas with low provision of musculoskeletal clinics.

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List of Abbreviations

NZ	New Zealand
GP	General Practitioner
GIS	Geographic Information System
NZDep2006	New Zealand Index of Deprivation 2006
CAM	Complementary or Alternative Medicine
ArcMap10	ArcMap GIS Version 10
ACC	Accident Compensation Corporation
HPCAA	Health Practitioners Competence Assurance Act
OCNZ	Osteopathic Council of New Zealand
SID	Supplier Induced Demand
LMI	Anselin Local Moran's I
OLS	Ordinary Least Squares
GWR	Geographically Weighted Regression
Gi*	Getis-Ord Gi*
AIC	Akaike's Information Criterion
GMI	Global Moran's I
HH	High-High
LL	Low-Low
HL	High-Low
LH	Low-High
CBD	Central Business District

Chapter One.

Introduction

Geographical and socioeconomic inequalities in life expectancy in New Zealand grew to reach historically high levels in the mid-1990s (Pearce & Dorling, 2006), prompting growing interest in the concept of healthcare accessibility in order to understand and address this issue. Healthcare accessibility has many dimensions, and geographical accessibility, defined as the extent to which the population finds the distance, travel time and means of transport to healthcare services acceptable (World Health Organisation, 1978), is arguably one of the most fundamental, since an inability to physically reach a healthcare provider may effectively nullify any treatment which may otherwise be available.

The increasing availability and sophistication of geographic information systems (GIS) in recent years has increased the approaches available in the study of healthcare accessibility. Although a number of studies investigating the geographical accessibility of healthcare facilities have used GIS to focus on estimates of travel times and measurement of distances between residential areas and healthcare facilities (Hawthorne & Kwan, 2012; Huang, Dignan, Han, & Johnson, 2009; J. Pearce, Witten, Hiscock, & Blakely, 2007), such time and distance measurements may be of limited utility when related to the study of healthcare clinic locations in an urban environment. Estimations of travel time in an urban area are often rough at best, due to the wide variations in travel times that may occur as a result of large fluctuations in traffic volume throughout the day (Hensher, 2001). Furthermore, patients requiring the services of primary healthcare clinics in New Zealand are free to seek care at their clinic of choice, and such a decision may be the result of a number of influences. For instance, a clinic in close proximity to a particular residential address may be perceived by the residents as less geographically accessible if the residents conduct a daily work commute across the city. Accordingly, GIS-based spatial statistical analyses that produce mapped representations of the spatial distribution of clinics across the study area, for example Kernel Density, Getis-Ord G_i^* and Local Moran's I (Mitchell, 2005), are particularly useful in the urban environment because they allow flexible interpretation of results. Inspection of output maps may reveal areas of high and low clinic density, and an

individual's resulting interpretation of the geographical accessibility of these facilities is likely to be as nuanced as the lifestyle and travel options available to each person.

Following description of the spatial patterns of clinic locations, regression modelling statistics may be used to identify relationships between clinic locations and physical and social aspects of the urban environment. GIS tools, such as Ordinary Least Squares and Geographically Weighted Regression, allow the incorporation of spatial elements of the environment into regression modelling statistics and provide diagnostic measures to determine and quantify any existing relationships. The information gained from these analyses may offer insights into the influence of demographics, socioeconomic status and the physical environment on clinic location.

Despite the high prevalence of musculoskeletal disorders in the population (N. Pearce et al., 2004; Taylor, Smeets, Hall, & McPherson, 2004), the geographical accessibility of primary healthcare facilities specialising in the care of musculoskeletal conditions in New Zealand has not been assessed. Osteopaths, physiotherapists, chiropractors, acupuncturists, and podiatrists collectively represent allied or complementary and alternative medicine (CAM) treatment options for patients with musculoskeletal symptoms, which if utilised appropriately could partially relieve the substantial burden of musculoskeletal disorders both in society and in the general practice workload. However, there is evidence to suggest a demographic divide between patients seeking GP care for a musculoskeletal complaint and patients seeking CAM care, with the former more likely to be male, older and living in a socioeconomically deprived area (Taylor et al., 2004), and the latter more likely to be female, middle aged, and with a high income and education (Ministry of Health, 2008; Orrock, 2009; Peachey, 2011; Pledger, Cumming, & Burnette, 2010). It is possible that the geographic placement of musculoskeletal clinics is one reason for the observed demographic divide between GP and CAM patients.

Auckland is the largest city in New Zealand (NZ), with an estimated population of over 1.5 million residents (Statistics New Zealand, 2012a). Auckland has been the fastest-growing region in NZ over the last decade, and in the year to June 2012, Auckland's population growth of 21,700 residents accounted for three quarters of NZ's population growth (Statistics New Zealand, 2012b). Such high levels of growth within one city mean that health

resource assessment and planning is vital in order to ensure service provision matches the needs of the population, and GIS offers the means to conduct such a study.

The study reported in this thesis has two main aims. The first aim is to determine the extent to which the geographic distribution of musculoskeletal clinics varies across urban Auckland. The GIS-based Kernel Density, Getis-Ord G_i^* and Local Moran's I statistics are employed to quantify the degree of variation, producing mapped representations of clinic distribution patterns across urban Auckland. Following on from these descriptive analyses, the second aim of this study is to identify factors which may underlie variations in the spatial pattern of clinic locations. Using GIS-based Ordinary Least Squares and Geographically Weighted Regression techniques, clinic distribution throughout urban Auckland is correlated with census-derived population statistics, alongside mapped physical elements of the urban environment. Regression models describing the nature and strength of the relationships between clinic locations and social and physical elements of the environment are produced. This study was conducted as a component of the Master of Osteopathy degree, therefore the focus of this thesis is on osteopathic clinics, with the inclusion of comparable privately-run musculoskeletal clinics to provide context, and GP clinics for comparison to a publicly-funded primary care facility.

This thesis is presented in the traditional style. Chapter two is a literature review that explores some of the factors which may be relevant to inequalities in health in New Zealand, discusses the impact of residential proximity on utilisation of health resources and critically evaluates the current literature related to the measurement of the geographic accessibility of various forms of healthcare. Chapter three describes the data collection and analysis techniques of the study, and provides reference to previous works utilising these techniques within various contexts. Chapter four contains the results of the investigation. Chapter five is a discussion section, in which the results of this investigation are contextualised alongside related local and international studies, and its limitations as well as potential directions for future research are identified. The appendices contain material supplementary to this thesis, including descriptions of variables used in the New Zealand Index of Deprivation, attributes of urban centres, and supplementary results of statistical analyses conducted in this study.

Chapter Two.

Literature Review

2.1 Introduction

The broad concept of healthcare accessibility has received much attention in recent years. Geographical accessibility to healthcare has been defined as the extent to which the population finds the distance, travel time and means of transport to healthcare service acceptable. Although geography is only one component of the accessibility equation, it is arguably the most fundamental, as an inability to physically reach a healthcare clinic effectively nullifies any treatment which may otherwise be available. Government initiatives to ensure an equitable supply of publicly-funded primary healthcare across the socioeconomic gradient appear to have had some success in terms of geographical accessibility; however the diverse healthcare needs of the population may require a range of practitioners from different healthcare modalities with the skills to communicate and collaborate in the patient's interests. Musculoskeletal disorders represent a substantial health burden, both within society and to the general practice workload, and while a number of complementary musculoskeletal healthcare options are available, without any centralised planning of service provision, the geographic distribution of such healthcare may be subject to a number of influences that may not take into account the healthcare needs of the population.

This review explores some of the factors which may be relevant to inequalities in health in New Zealand, describes the tools typically used to measure geographical accessibility to healthcare, and discusses the possible impact of residential proximity on utilisation of health resources. The review also describes and critically evaluates the current literature related to the measurement of the geographic accessibility of various forms of healthcare.

2.2 Health inequalities in New Zealand

Geographical inequalities in life expectancy in New Zealand rose sharply from the late 1980s to reach historically high levels by the mid-1990s, as life expectancy for people living in the least deprived areas rose sharply, while more deprived groups did not keep pace (J. Pearce & Dorling, 2006). Analysis of mortality records within regional health geographical areas between 1980 and 2000 showed that by the year 2000 there was a clear relationship between relative deprivation of an area and life expectancy (J. Pearce & Dorling, 2006). For example, between 1997 and 1999, men and women living in the most deprived areas of the country were reported to have an average life expectancy of 9.5 years and 6.2 years less than their counterparts living in the least deprived areas (Tobias & Jit, 2003).

Accompanying the growing inequality in life expectancy were fundamental changes in the delivery of primary healthcare. In the late 1980s and early 1990s, New Zealand health sector reforms removed centralised planning and development for the primary healthcare workforce with the contention that competition and market forces would drive health workforce development (Health Workforce Advisory Committee, 2003). This shift in policy drew criticism from many commentators, including an editorial published a decade after the policy changes in the New Zealand Medical Journal which stated “until a balance is restored in central government between the free market ideology and the needs of the society as a community, then we will continue to have failure of services” (Nicholls, 2001). A report by the Health Workforce Advisory Committee (2003) reported that the “laissez-faire” arrangement throughout the 1990s had resulted in an infrastructure incapable of supporting workforce development and planning, and argued that a paradigm shift was required to deliver primary healthcare effectively.

The fifth New Zealand Labour government introduced the New Zealand Health Strategy (‘the Strategy’) in 2001, which outlined a ‘population health’ approach aimed at reducing the socioeconomic health gradient and matching the health practitioner to patient ratio with the healthcare needs of the population (Ministry of Health, 2001). The long-term priorities identified in this document have continued to form the basis for health policy under two successive National-led coalition governments. Despite the significant funding and structural changes in the delivery of healthcare that were designed to ensure accessibility for every member of the population, health inequalities have persisted

throughout the 2000s. The most recent data provided by the Ministry of Social Development (2010) documents the period 2005 – 2007, during which the life expectancy of males living in the most deprived tenth of residential areas was 8.8 years less than males living in the least deprived tenth of residential areas. For females, the difference was smaller, but still substantial, at 5.9 years (Ministry of Social Development, 2010). It must be recognised that The Strategy is a long-term project, and as such, significant changes in life expectancy as a result of policy changes may take several years to become apparent; however until more recent national data becomes available assessment of the evolving situation is difficult.

The Strategy bases many of its core guiding principles on the World Health Organisation's 1978 Declaration of Alma Alta, written during the International Conference on Primary Health Care (World Health Organisation, 1978). In this declaration, accessibility was identified as a key component of primary healthcare provision. The declaration separates the concept of healthcare accessibility into four interrelated components: geographical, financial, cultural and functional. Geographical accessibility means that the population finds the distance, travel time and means of transport to healthcare services acceptable. Financial accessibility means that the services can be afforded by the population. Cultural accessibility means that the cultural patterns of the population are respected throughout the provision of healthcare. Functional accessibility means that continuity of care provided by an appropriately skilled health team is available to whoever needs it, whenever they need it. Although the many dimensions of accessibility make accurate universal accessibility measurement problematic (Brabyn & Gower, 2004), perhaps the most fundamental component of access is geographical: the ability of the patient to reach the clinic's physical location.

2.3 Tools to measure geographic accessibility

The development of sophisticated geographic information system (GIS) computer programs has allowed researchers to address the geographical component of access to healthcare via spatial statistics. "GIS is a software system and group of procedures that provide data input, storage and retrieval, mapping, and spatial analysis for both spatial (location and shape of geographic features) and attribute (characteristics of the spatial features) data to support the decision-making activities of an organization" (Carlson, York, & Primomo, 2011, p. 160).

Whereas traditional statistics often involves analysis of tables of attribute values, spatial statistics uses maps to incorporate analysis of feature locations and spatial relationships alongside tables of attribute values (Mitchell, 2005).

Spatial queries often involve analysis of an entire population rather than the random sampling procedure of traditional statistics that utilise probability theory. However, spatial analysis may still use inferential statistics by employing the randomisation null hypothesis. Mitchell (2005) explains that while the attribute values of each feature are fixed, their spatial arrangement is considered to be only one of many possible patterns. The randomisation null hypothesis states that if the spatial arrangement of features could be rearranged an infinite number of times, most of the time the pattern would not be markedly different from the observed pattern. If the significance test used in a spatial query indicates that the null hypothesis should be rejected at a specified confidence level, then the observed arrangement of features would significantly differ from a randomly produced pattern (Mitchell, 2005).

In an urban environment, the characteristics of the population are a fundamental force shaping the physical surroundings, and it may be therefore be theorised that clinic accessibility may be influenced by both geographical and social features of a neighbourhood. GIS allows measurement of many such features against various outcomes. For example, in an investigation of obesity-promoting food environments, Day and Pearce (2011) used GIS to determine if fast food outlets and convenience stores are clustered around schools in New Zealand, and the relationship of demographic characteristics to any such clustering. These authors showed that outlets were most clustered around those schools in socioeconomically deprived, densely populated and commercially zoned areas, thus implicating both geographical (land zoning) and social (population density and socioeconomic level) features of the environment.

While free access to data regarding geographical features of the urban landscape is readily available from government departments, accurate data pertaining to the social elements of the environment is less easy to obtain. Within New Zealand, data collected in the 2006 New Zealand Census of Population and Dwellings is the most recent national survey data available, and offers the advantage of working with a high quality data set that is as close to

being representative of the population as is likely to be achieved (Bryman, 2008). Census data regarding small areas is often aggregated to the level of meshblock or Area Unit. A meshblock is the smallest geographic unit for which statistical data is collected by Statistics New Zealand. Meshblocks have an average residential population of 100, therefore their size depends on population density, and can vary from part of a city block to large areas of rural land (Statistics New Zealand, n.d.-d). Meshblocks aggregate to build larger Area Units, which generally coincide with suburbs and contain a population of 3,000 to 5,000 residents (Statistics New Zealand, n.d.-d). Such data is utilised with the understanding that aggregate data is not suited to the analysis of individual behaviours (Corbetta, 2003), but may be useful in providing an overview of the social environment.

2.4 Practice proximity may impact utilisation of healthcare services

Residential proximity to community resources such as health and recreational facilities has been theorised to contribute to health and wellbeing by reducing time and transport cost barriers to access (J. Pearce, Witten, & Bartie, 2006). Indeed, research using GIS has linked residential proximity to higher utilisation of these resources. For example, Hiscock, Pearce, Blakely, and Witten (2008) used a GIS to measure travel times between meshblocks and the nearest General Practice and pharmacy, and compared this data with the 2002/2003 New Zealand Health Survey results. These authors created a logistic regression model which indicated that respondents living in the quartile of neighbourhoods with the longest travel times to the nearest General Practice were less likely to have had a General Practitioner (GP) consultation in the last year (Odds Ratio 0.74 [0.63–0.87]) compared with respondents living in the quartile of neighbourhoods with the shortest travel times. Furthermore, survey respondents with the longest travel times were less likely to have received blood pressure and cholesterol tests or to have utilised pharmacies in comparison to respondents with shortest travel times (Hiscock et al., 2008). Although this cross-sectional data cannot provide any evidence of a causal relationship, and it is possible that people who wish to access these services regularly may have chosen to live near them, the results of this research highlight the possible importance of residential proximity to practice location for healthcare accessibility.

It is often assumed that differential access to neighbourhood resources such as health facilities is one partial explanation for the observed gap in health between deprived and

non-deprived neighbourhoods (J. Pearce et al., 2007). This assumption is based on the 'inverse care law', whereby "the availability of good medical care tends to vary inversely with the need for it in the population served" (Hart, 2000, p. 18). This law is thought to apply when the healthcare system is exposed to free-market forces, as it is, to some extent, in New Zealand. Although research has demonstrated evidence of the inverse care law in the United Kingdom (McLean, Sutton, & Guthrie, 2006; Mercer & Watt, 2007), it appears that the situation for many health resources is opposite in New Zealand. A study used GIS to measure the travel distance and time between meshblocks and beneficial health resources such as recreation, food shopping, education, marae and conventional medical healthcare facilities throughout New Zealand (J. Pearce et al., 2007). The results of this study indicated that geographical access to most health-related community resources, especially healthcare facilities, was actually better in the more deprived neighbourhoods of the country (J. Pearce et al., 2007). The accessibility index created by these authors was based primarily on travel times calculated by using GIS to create a representation of the road system and adjusting travel times for features such as speed limits, road surfaces and topography to create more realistic estimates of travel times (J. Pearce et al., 2007). While this method demonstrates the sophisticated level of analysis possible using GIS software, the utility of the data is limited when these methods are used at a nationwide level, as the sheer amount of information generated requires results to be reported only in very broad terms. These terms cannot capture the neighbourhood or even inter-city variations which are bound to exist in this type of data. In addition, these methods may be better applied to rural areas with more predictable travel times, in comparison to the wide variations in travel times that are often experienced in urban areas as a result of fluctuations in traffic volume.

Finally, J. Pearce et al. (2007) did not measure geographical access to allied or complementary healthcare resources such as osteopathic, chiropractic, physiotherapy, acupuncture or podiatry clinics. Such an omission could be important, as the healthcare services available at a GP clinic alone may not be sufficient to meet the diverse healthcare needs of the population. As stated by the NZ Ministry of Health, no single practitioner or type of practitioner can meet people's needs completely, instead, a range of practitioners with the skills to communicate and collaborate in the patient's interests are needed (Ministry of Health, 2001).

The results of the study by J. Pearce et al. (2007) indicating that geographical access to GP facilities are better in the more deprived neighbourhoods of the country may be related to various government initiatives in past years which have sought to rebalance the supply of medical care by influencing the geographic distribution of GP clinics in New Zealand. Examples include encouraging and facilitating rural placements for medical students, because exposure to rural medicine during undergraduate training has been shown to be a positive predictor of future rural practice (Bagg et al., 2010). Funding has been made available for additional medical school places for rural-origin students (Goodyear-Smith & Janes, 2008), and the choice of practice location has been restricted for immigrating doctors (Janes, Dowell, & Cormack, 2001). For many years, rural GPs have received a 'rural bonus' to offset the financial burdens of rural practice (Goodyear-Smith & Janes, 2008). Furthermore, the Strategy aims to assess health and disability needs on a regional basis, and target services to these needs. Under the aims of the Strategy, regions with specific healthcare needs, for example socioeconomically deprived areas, would be given service priority (Ministry of Health, 2001). Funding for health services is currently based on capitation payments reflecting the size, demographics and specific health care needs of the enrolled population (Ministry of Health, 2001). Finally, the Strategy also states that specific services for Maori and Pacific people should be made available, and gives the example of health service provision on marae and at kohanga reo, schools and specialised clinics (Ministry of Health, 2001).

2.5 Differing characteristics of musculoskeletal practice and GP musculoskeletal patients

Musculoskeletal disorders can involve any of a wide variety of conditions causing stiffness and pain in the muscles, tendons, joints, bones, or nerves, and represent a substantial burden in general practice. The extent of this burden was demonstrated by a study that collected consultation data from 22 New Zealand general practices over a one-year period, and calculated that of the 29,152 attending patients, 20% consulted with a musculoskeletal disorder (Taylor et al., 2004). These authors developed a logistic regression model for the probability of being a person who consulted with a musculoskeletal disorder, showing the independent effects of gender, socioeconomic deprivation and age. The results of these calculations indicated that older people, males, and people who lived in more socioeconomically deprived areas, were more likely to consult with a musculoskeletal

disorder than younger people, females and people living in the least deprived areas respectively (Taylor et al., 2004).

Alongside GP care, patients seeking care for musculoskeletal disorders in New Zealand have a wealth of specialised musculoskeletal healthcare options available, and are protected by legislation governing a wide range of practice modalities that is designed to ensure practitioner competency. Osteopaths, physiotherapists, podiatrists and chiropractors are amongst the healthcare modalities that practice under the Health Practitioners Competence Assurance Act 2003 (HPCAA) (Ministry of Health, 2011). The HPCAA requires practitioners in regulated professions to be registered with a modality-specific governing body that certifies practitioner competence on an annual basis (Ministry of Health, 2013).

Additionally, under the Accident Compensation Corporation (ACC) scheme, patients suffering an accidental injury may be eligible for government-subsidised therapy from the modalities listed above, as well as acupuncture (Accident Compensation Corporation, 2012).

Osteopathy is a growing healthcare profession in New Zealand, with 402 registered osteopaths holding annual practising certificates in 2013 (Osteopathic Council New Zealand, n.d.), compared to an estimated 304 practising osteopaths in 2003 (Adams, 2003). The osteopathic profession has a unique philosophy in its understanding of health and wellbeing, distinguished by the concept that much pain and disability stems from abnormalities in the interrelationship between the body's structure and function, as well as damage caused to it by disease (Parsons & Marcer, 2006). While there is no strict definition for osteopathy, it is widely accepted that the principles that underpin osteopathic diagnosis and treatment emphasise the integrity of musculoskeletal elements of the body, and may therefore be of particular benefit to patients with musculoskeletal health conditions.

Accordingly, musculoskeletal disorders appear to represent the reason for the majority of presentations to osteopathic practitioners. For example, an Australian survey of 2,238 Australian osteopathic patients indicated that the predominant first presenting symptom was musculoskeletal pain (82.7%), with a small (7.8%) group of patients complaining primarily of immobility. The location of these symptoms was overwhelmingly in the lumbar spine (27.3%) and neck (24.5%) followed by head (9.8%) and then other regions of the body (Orrock, 2009). Similar symptom locations and frequencies have been described amongst

physiotherapy patients (Holdsworth, Webster, & McFadyen, 2006), chiropractic patients (Coulter et al., 2002) and acupuncture patients (Culliton, 1997), while it appears that podiatry patients tend to present predominantly with foot pain (Menz, Gill, Taylor, & Hill, 2008). Collectively, these healthcare modalities represent treatment options for patients with musculoskeletal symptoms, which if utilised appropriately could relieve the substantial burden of musculoskeletal disorders in general practice, estimated by Taylor et al. (2004) to account for 20% of all GP consultations.

At various times, osteopathy has been described as an allied or complementary or alternative medicine (CAM) modality, and while there is no strict definition on where osteopathy fits in the healthcare system, research has often included it within the CAM group. A number of studies have described the characteristics of patients consulting osteopathic and CAM practitioners. Cumulatively, these studies indicate that the characteristics of osteopathic patients contrast with Taylor et al.'s (2004) calculations indicating that older people, people living in a socioeconomically deprived area and males were more likely to consult a GP with a musculoskeletal disorder. Two surveys of Australasian osteopathic patients demonstrate this contrast (Orrock, 2009; Peachey, 2011). Orrock's (2009) survey of 2,238 Australian osteopathic patients found that 63% were female, 46% were between the ages of 30 – 49 years and 56% described their occupation as professional, managerial, clerical or technical. A survey by Peachey (2011) of 287 patients visiting five osteopathic clinics in Auckland found that females, Europeans and professionals were over-represented in the osteopathic patient population in comparison to Auckland's statistical demographic distribution. In addition, 67% of the patients surveyed were aged between 30 – 59 years (Peachey, 2011).

Similar characteristics have been found by studies describing CAM users more generally. A systematic review of 110 studies that investigated the characteristics of CAM users determined that the evidence overall suggests that people who use CAM tend to be female, middle aged and with a higher education and income level than non-users (Bishop & Lewith, 2010), however osteopathy was not included as a treatment option in all of these studies. Although no New Zealand studies were included in this review, New Zealand data concurs with the results of the international studies reviewed by Bishop and Lewith (2010). Pledger et al. (2010) analysed data collected from 12,529 people interviewed in the 2002/2003 New

Zealand National Health Survey, in which osteopathy was included in the list of CAM healthcare providers. These authors concluded that people who used CAM were more likely to be middle-aged, female, of European descent and highly educated with a high income. Data collected in the later 2006/07 New Zealand National Health Survey indicated that 15% of women living in the most deprived areas had seen a CAM worker in the past 12 months, compared to 26% of women living in the least deprived areas (Ministry of Health, 2008). In contrast, no similar differences between GP service utilisation and neighbourhood deprivation were found (Ministry of Health, 2008). The disparity between these results suggests that CAM therapies may be less accessible than GP care for people living in deprived areas.

As privately paying customers, osteopathic patients are not bound by District Health Board territorial boundaries, and are free to seek osteopathic care at their clinic of choice. Such a decision can incorporate any number of factors, however it may be assumed that many patients may be bound by the time and financial cost of travel and thus may choose a clinic based on convenient access to their home or workplace. Peachey's (2011) survey of 287 patients visiting five osteopathic clinics in Auckland found that the majority of patients lived within the same area as the clinic they attended. In the three clinics located in the Rodney district in northern Auckland, 82 per cent of patients surveyed lived in the Rodney area, and in the two central Auckland clinics, 70 per cent of patients surveyed lived within central Auckland (Peachey, 2011). Central Auckland is New Zealand's major business and commercial centre, with thousands of people travelling to the area every day from all over Auckland (Statistics New Zealand, n.d.-b). The relatively lower percentage of resident patients in central Auckland compared to Rodney may indicate that some people choose to visit an osteopathic clinic in closer proximity to their workplace than their home. Nonetheless, it appears that the majority of patients access services within their area of residence, even in Central Auckland. Peachey's (2011) study also highlighted the idea amongst osteopaths that patients will "drive from the far end of the earth to come and see 'their osteopath'" (p. 55). This occurrence may be true for the sector of society currently accessing osteopathic care; however it is possible that the time and financial cost of travelling to a clinic is one of the factors preventing some groups within society from seeking care.

2.6 Potential factors influencing the geographic accessibility of musculoskeletal clinics

Government policies to influence the geographic distribution of healthcare providers, such as those applied to GP clinics, have not been administered to the osteopathic profession or any other CAM or allied health providers running privately funded clinics. Without a governing body policy or funding to encourage the development of osteopathic clinics in locations that may help to equitably serve the health needs of the population, osteopathic practice location may be subject to any number of influential factors, many of which may be largely commercial in nature.

Several studies have reported on the influence of practice location in conventional medicine settings. For example, a survey of General Practitioners in South-East England found that the most important influence on the respondents' choice of practice location was aversion to location in an area of high socioeconomic deprivation (Gosden, Bowler, & Sutton, 2000). Other factors identified in this study included a preference for areas with established primary healthcare teams, opportunities for outside interests, higher income and shorter working hours (Gosden et al., 2000). A survey of Physician Assistants in the United States identified similar factors, alongside the importance of also being able to live in a location that was supported by, and offered opportunities for, a significant other (Smith, Muma, Burks, & Muck Lavoie, 2012). Osteopaths, residing in Auckland, New Zealand, who were interviewed in a recent study by Peachey (2011) identified the importance of clinic location on a main arterial road which is unaffected by traffic jams, having identifiable landmarks around the clinic, and the physical characteristics of the building itself, such as the undesirable presence of flights of stairs. The prestige of working from a particular location, overhead expenses, professional support, presence of a strong target market, and regions with improving population growth and prosperity have also been suggested as influential factors on osteopathic clinic location (Adams, 2003).

A number of international studies have suggested or investigated various aspects of the influence of geography and the physical and social environment on the location of CAM or allied healthcare clinics. For example, clinic location may be influenced by the location of other businesses offering similar services. Meyer (2008) discusses the idea of agglomeration economies, or the benefits and/or cost savings that businesses derive by clustering within a

geographic area, which are commonly described in two ways: localisation economies and urbanisation economies. Localisation economies occur when similar businesses producing similar things cluster together in space and benefit from proximity advantages such as the ability to participate in industry-specific knowledge exchanges (Moomaw, 1988). In the context of healthcare, clinics may benefit from being in close proximity to other similar clinics by virtue of increased patient referrals. Urbanisation economies are the advantages of scale that extend to all businesses in urban areas, with such advantages including a varied workforce, developed infrastructure, high levels of business services and interactions and a large local market (Moomaw, 1988).

Meyer (2008) used GIS to determine if there was evidence of an agglomeration economy amongst CAM (in this instance, acupuncture, chiropractic, massage therapy, homeopathic and naturopathic) clinics in four cities in Ontario, Canada. Creation of a 'nearest neighbour' index using a GIS indicated if the observed pattern of location points deviated from a theoretical random distribution sufficiently to be considered significantly clustered or dispersed in space (Mitchell, 2005). The CAM clinics included in the analysis were shown to have a strong tendency to be clustered, indicative of evidence of a localisation economy (Meyer, 2008). Additionally, the location of these clusters was consistently found within central downtown areas, implying that CAM clinic locations may also be influenced by the advantages of an urbanisation economy (Meyer, 2008).

Further to the idea of agglomeration economies, the concept of 'supplier induced demand' (SID) suggests that higher numbers of practitioners coincide with increased utilisation of services by individuals (Richardson & Peacock, 2006). This concept implies that clinics may benefit from locating in areas already supplied with healthcare services, thus creating a pattern of supply and demand which is not geographically balanced. According to standard economic theory, an increase in supply is expected to be followed by a decrease in suppliers' earnings and in the prices of their services (Liu & Mills, 2007). However, this theory is not considered to explain the market for healthcare, following the observation by Roemer (1961) that "a bed built was a bed filled", later translated into the concept of SID (Léonard, Stordeur, & Roberfroid, 2009). Theorists state that in cases where medical fees are not regulated, an increase in the supply of doctors may also be followed by an increase in fees (Liu & Mills, 2007). Indeed, much of the research investigating this phenomenon has

focussed on the concern that doctors may deviate from their professional responsibilities by providing or recommending further unnecessary healthcare procedures to individual patients with the objective of increasing their own earnings (Léonard et al., 2009). Although a higher rate of healthcare consumption may intuitively be considered a normal effect of greater availability of care, increased physician density may also have an effect on the amount of care received by each patient (Léonard et al., 2009). For example, in some cases recommendation of a follow-up visit may occur only if the physician's workload is manageable, which is more likely in areas with higher physician density (Léonard et al., 2009). A systematic review of research investigating the existence of SID found that a significant positive correlation between physician density and all healthcare consumption by individuals was consistently observed across the 25 studies reviewed (Léonard et al., 2009).

Although the majority of research regarding SID has focussed on the supply of conventional medicine, recent studies have begun to examine the relationship between CAM supply and use. Whedon, Song, Davis, and Lurie (2012) analysed the supply and use of chiropractic services amongst health insurance users in the United States, using patient data supplied by health insurance providers and GIS software to perform small area analyses. The results of these analyses indicated that chiropractic supply and use were positively correlated (Spearman 0.68; $p = 0.001$), (Whedon et al., 2012), which may suggest a degree of SID exists for chiropractic treatment in the United States. These findings may also in turn have been influenced by other factors, such as the socioeconomic status of the surrounding residential areas creating a more desirable location for a clinic. A notable point is that Whedon et al. (2012) only examined the use patterns of patients seeking care funded by health insurance. Because this care was funded by an insurance company rather than out-of-pocket, patients may have been more eager to utilise the service, potentially adding bias to the calculations of correlation between use and supply. A more objective measurement may have incorporated the chiropractic use patterns of both insured and uninsured patients.

Meyer (2009) discusses the idea that CAM practitioners are often also proprietors, and like all businesses, are at least partially motivated by profit. As a result, areas with high levels of economic prosperity may provide better markets for CAM services which typically require out-of-pocket payments. In Meyer's (2009) study, the GIS-based Global and Local Moran's I statistics were utilised to determine if CAM (chiropractic, acupuncture, massage therapy,

homeopathic and naturopathic) clinics in Ontario, Canada were significantly clustered or dispersed in their spatial distribution. The results of this analysis were merged with digital maps containing census-derived attributes of the area, such as average incomes, employment rates and population density, before Spearman's correlation analyses of the relationship between clinic distribution and social aspects of the environment were measured. The results of this study suggested that as economic prosperity increased, so did the likelihood that the area would have a higher per capita level of CAM healthcare supply (Meyer, 2009). A limitation of this study is that the geographic units of measurement reported are census subdivisions, which are essentially municipalities (Meyer, 2009). Because the municipalities have populations ranging from tens of thousands to several million, measurement of the census-derived social aspects of the environment is very coarse and may not capture the neighbourhood-level socioeconomic variation inherent in such environments, highlighting the benefit of undertaking a more detailed measurement within just one city. However, this study succeeds in indicating the influence of economic prosperity on CAM clinic locations on a broad scale by utilising robust and appropriate spatial statistical methods.

An investigation of the geographic distribution of dental clinics in New Zealand also noted a relationship between clinic supply and economic prosperity (Kruger, Whyman, & Tennant, 2012). Like osteopathic care, dental care in New Zealand is provided primarily within private practices; although government funding is available for dental care for under-18 year olds and some beneficiaries. A 2012 study used GIS to examine the distribution of private dental practices in Auckland, Wellington and Christchurch in New Zealand, and found that available care was concentrated largely in areas of high socioeconomic status and in populations with lower levels of oral disease (Kruger et al., 2012). The study showed that in the wealthiest 20% of Area Units, the practice : adult population ratio was 1 : 3000, while the poorest 20% per cent of Area Units had a ratio of 1 : 5500 (Kruger et al., 2012). Ethnic disparity was also evident. Area units in which Maori and Pacific Islanders represented greater than 30% of the population featured a practice : adult population ratio of 1 : 15,400, while area units in which Maori and Pacific Islanders represented less than 10% of the population had a practice : adult population ratio of 1 : 250 (Kruger et al., 2012). It must be noted that these authors used simplistic methods to define the city limits,

measuring only the area inside a 15 kilometre radius of each city's respective town hall. This method does not take into account the substantial differences in size between each city, with the southern limits of urban Auckland, the largest city in New Zealand, lying more than twice the distance these authors measured from the town hall. Given the wide variation in socioeconomic status between central and southern Auckland neighbourhoods (White, Gunston, Salmond, Atkinson, & Crampton, 2008), the findings of this study may have been considerably different had the entire urban region been incorporated. A more accurate result could have been achieved by accessing GIS files containing the actual city limits, available free of charge from online databases such as Koordinates.com [Koordinates Ltd, Auckland, NZ]. Despite its shortcomings in GIS methodology, this study does demonstrate that within a primarily privately funded, market-driven health profession, services may be more geographically accessible within less socioeconomically deprived neighbourhoods. However, these results cannot be extrapolated to musculoskeletal clinics due to the significant differences in the services provided in dental and musculoskeletal clinics.

A 2003 study examining the geographic distribution of osteopaths in New Zealand provides some indication that the osteopathic workforce may not be evenly distributed, either in New Zealand as a whole, or within Auckland City. Adams (2003) conducted a survey of the practice locations of 304 registered osteopaths, and found that the North Island, with 76% of the national population, held 86% of the osteopathic workforce. Within the Auckland region, Manukau had only 0.13 full-time osteopaths per 10,000 people, while Waitakere had 1.03, Auckland City 0.97 and the North Shore had 0.80. While this study provides an interesting snapshot of osteopathy in New Zealand, analysis of the geographical accessibility of osteopathic practices across the socioeconomic gradient is limited because the data is analysed only to the geographical level of Territorial Authority (TA). Each TA consists of an aggregation of many small residential areas, therefore the mean deprivation level of each TA may not be reflective of the socioeconomic position of many of its residents. In addition, while data collected from within each TA is treated as a distinct group, in reality the borders of each TA are adjacent, meaning that patients residing in close proximity to the border may find it easier to access a practitioner in another TA rather than within their own. Furthermore, Adams' (2003) study was conducted prior to the graduation of the first cohort of Unitec-trained osteopaths at the end of 2003. With a further nine cohorts joining the

workforce since then, and the number of registered osteopaths in New Zealand rising from 304 in 2003 (Adams, 2003) to 402 in 2013 (Osteopathic Council New Zealand, n.d.) there is potential for the geographic distribution to have altered substantially in this time period.

2.7 Conclusion

Musculoskeletal disorders constitute a substantial burden in general practice. Osteopathy, physiotherapy, chiropractic, acupuncture and podiatry represent allied or CAM treatment options for patients with musculoskeletal disorders, which if utilised appropriately could partially relieve the burden of such disorders, both in society and in the general practice workload. However, it appears that osteopathic and other CAM healthcare services may currently be accessed predominantly by people living in the least deprived areas of New Zealand. Geography, in the form of clinic location, plays a fundamental role in healthcare accessibility, as an inability to physically reach a clinic effectively nullifies any treatment that may otherwise be available. While the geographic accessibility of publicly-funded GP clinics in New Zealand may be influenced by government policies aimed at ensuring equitable access to primary healthcare across the socioeconomic gradient, it may be expected that the locations of privately-funded musculoskeletal healthcare clinics are subject to different influences. Although a number of studies have suggested factors which are potentially influential on clinic locations, there has been no measurement of the spatial arrangement or influential forces on the location of musculoskeletal clinics in New Zealand. Such measurement will provide an overview of the current situation which may be useful in planning the delivery of health care for the growing population. The following chapters of this thesis report on an investigation which aims to determine the extent to which the geographic distribution of osteopathic and related healthcare clinics varies across urban Auckland, and to determine factors which may be related to variations in the spatial pattern of clinic locations.

Chapter Three.

Research Methods

3.1 Data Collection

3.1.1 Practice addresses

The focus of this study was on osteopathic clinics, with the inclusion of comparable privately-run musculoskeletal healthcare clinics (physiotherapy, chiropractic, acupuncture, and podiatry) to provide context, and GP clinics for comparison to publicly-funded primary care facilities. All data were collected from open-access sources and thus no ethical approval was required. Internet-based practitioner databases were searched in May 2012 to obtain the addresses of osteopathic, physiotherapy, podiatry, chiropractic, acupuncture and GP clinics. The latitude and longitude of each address were obtained through a free-access geocoding website (Schneider, 2013) and converted to GIS-compatible point data using ArcMap Version 10 (ArcMap10) [Environmental Systems Resource Institute (ESRI), Redlands, CA, USA]. To test the integrity of the geocoding process, a randomly selected confirmatory sample of 10% of all geocoded clinic locations was corroborated against personal knowledge and other web-based information located using the search engine Google.com [Google, Inc., Mountain View, CA, USA]. No inaccuracies in the geocoded clinic locations were observed.

For the purpose of analysis, each modality was examined individually where appropriate, or aggregated as musculoskeletal clinics (osteopathic, physiotherapy, podiatry, chiropractic and acupuncture) for comparison with GP clinics.

3.1.2 Map data

GIS polygon maps of Auckland's meshblocks (Statistics New Zealand, n.d.-c) and Area Units (Statistics New Zealand, 2011b) were downloaded from Koordinates.com (Koordinates, 2009), an online geographical data repository [Koordinates Ltd, Auckland, NZ]. GIS polygon files of Auckland's zoning and urban-rural boundaries were obtained from the GeoSpatial Team at the Auckland Council (P. Lee, personal communication, August 21, 2012).

A GIS line map of Auckland's road network was obtained from Land Information New Zealand (2011) and edited according to the Auckland Council's (2013) colour-coding system for identifying major and arterial roads.

3.1.3 Independent variables

The New Zealand Index of Deprivation (NZDep2006) was used as a basis of the measure of local area socioeconomic disadvantage. The NZDep2006 is a composite measure derived from multiple weighted socioeconomic variables collected in the 2006 New Zealand Census and includes nine variables that either reflect or measure material and social disadvantage (see Appendix A) (White et al., 2008). Data relating the NZDep2006 and its individual components to each meshblock and Area Unit were obtained from Statistics New Zealand (n.d.-d) and joined to the polygon files as attributes. In regression analyses where the NZDep2006 was found not to be a significant explanatory variable, the index components were disaggregated and assessed individually. Related uses of the deprivation index have included investigations into the accessibility of food and alcohol outlets (J. Pearce, Day, & Witten, 2008), gambling facilities (Wheeler, Rigby, & Huriwai, 2006), and breast cancer treatment (McKenzie, Ellison-Loschmann, & Jeffreys, 2010).

In New Zealand, ethnicity has previously been shown to be related to healthcare accessibility (Kruger et al., 2012) and utilisation (Cumming, Stillman, Liang, Poland, & Hannis, 2010). 2006 census results describing meshblock and Area Unit population ethnicity were obtained from Statistics New Zealand (Statistics New Zealand, n.d.-d) and joined to the related polygon files as attributes.

3.1.4 GIS software

GIS data were collated and analysed using ArcMap10 [Environmental Systems Research Institute (ESRI), Redlands, CA, USA]. This software enables data regarding the physical and social attributes of an area to be mapped and analysed alongside the location and shape characteristics of geographic features (Mitchell, 2005).

3.2 Data Analysis

3.2.1 Data analysis overview

Kernel density, Getis-Ord G_i^* and Local Moran's I statistics were employed to determine the extent to which the geographical distribution of healthcare clinics varied across urban Auckland. Regression modelling using Ordinary Least Squares and Geographically Weighted Regression statistics was conducted to describe relationships between clinic locations and the urban environment.

3.2.2 Kernel Density

The kernel density calculation produces a surface raster that fits a smoothly curved surface over each point, with graduated colours symbolising the degree of density of a variable (Mitchell, 2005). The kernel function is based on the quadratic kernel function described in Silverman (1986). Kernel density maps showing population and clinic densities per Area Unit were produced to provide a visualisation of the possible relationship between clinic location and population density.

*3.2.3 Hot Spot Analysis: Getis-Ord G_i^**

Cluster analysis is useful in determining whether geographical accessibility of a variable may vary across a region and may result in the identification of 'hot' and 'cold' spots. A 'hot spot' refers to an area with relatively higher clinic density compared to surrounding areas, whereas a 'cold spot' indicates the opposite. The Getis-Ord G_i^* is a distance-based statistic that measures the proportion of a variable (clinic density per meshblock) found within a given radius of a feature (meshblock centroid), to the sum of the variable in the study region, and was employed for hot spot analysis (Esri, 2012; Mitchell, 2005; Zhang, Wong, So, & Lin, 2012). Previous health-related applications of the Getis-Ord G_i^* statistic include analysis of access to fresh produce in low-income neighbourhoods (Algert, Agrawal, & Lewis, 2006) and spatial patterning of malaria transmission (Yeshiwondim, Gopal, Hailemariam, Dengela, & Patel, 2009). As suggested by Ord and Getis (1995) and Mitchell (2005), the radius to be measured was determined by running the Global Moran's I tool at incremental distances and selecting a distance at which the z-score peaked, indicating maximum spatial autocorrelation, while still being small enough to capture subtle neighbourhood variations (see Appendix B). Distance conceptualisations selected were zone of indifference and

Manhattan distance (Mitchell, 2005). The output is a map of meshblock z-scores symbolising significant ($p < 0.05$) hot and cold spots.

3.2.3 Cluster and Outlier Analysis: Anselin Local Moran's I

While Getis-Ord G_i^* is useful to identifying hot and cold spots at a global level, the Anselin Local Moran's I (LMI) statistic identifies influential spatial outliers and clusters at a local level, and is therefore useful for decomposing the global hot spot analysis into neighbourhood-specific components (Anselin, 1995). The LMI statistic is a measure of spatial autocorrelation which compares attribute values (clinic density per Area Unit) of each feature (Area Unit) and each of its adjacent features to the mean attribute value for all features in the study area (Aguilar & Farnworth, 2013; Anselin, 1995; Mitchell, 2005). LMI results vary from +1 (strong positive spatial autocorrelation), indicating that areas with similar attribute values are located adjacent to one another, to -1 (strong negative spatial autocorrelation), indicating that areas with high attribute values are located adjacent to areas with low attribute values and vice versa. A result near 0 implies a lack of spatial pattern, indicating a random distribution (Schuurman, Peters, & Oliver, 2009). The null hypothesis is evaluated using a z-score created from the mean and variance of attribute values. Previous health related applications of the LMI statistic include spatial patterning of cardiac disease (Loughnan, Nicholls, & Tapper, 2008) and obesity (Schuurman et al., 2009). Following the work of Schuurman et al. (2009), groupings of six or more significant positive I results with significant z-scores in close proximity were considered to be strong evidence of clustering, while areas with significant negative I results amongst these groups was considered to weaken the evidence of clustering. Distance conceptualisations utilised were zone of indifference and Manhattan distance (Mitchell, 2005).

3.2.4 Ordinary Least Squares

Logistic regression statistics are useful for gaining an understanding of why features exhibit particular spatial patterns. Ordinary Least Squares (OLS) is the first step in geographical regression modelling because the OLS tool is the only logistic regression application in ArcMap10 that provides a number of diagnostic statistical measures necessary for full evaluation of the results, as described by Mitchell (2005) and Rosenshein, Scott, and Pratt (2011b) (see Table 1). The Exploratory Regression tool within ArcMap10 was used to build OLS models using all possible combinations of candidate explanatory variables and to assess

which models passed the necessary OLS checks (Rosenshein, Scott, & Pratt, 2011a). The OLS tool was used to provide a global model of the relationship between clinic density per Area Unit and a number of explanatory variables pertaining to physical and social features of the environment (see Table 2). The focus of this study was on osteopathic clinics, with the inclusion of other privately-run musculoskeletal modality clinics and GP clinics for comparison. Consequently, regression models were created for osteopathic clinics, aggregated musculoskeletal clinics (osteopathic, physiotherapy, chiropractic, acupuncture, and podiatry), and GP clinics.

Table 1.

Interpretation of OLS Output Statistics

Statistic	Interpretation
Variance Inflation Factor (VIF)	>7.5 indicates explanatory variable redundancy
Multiple R ² /Adjusted R ²	Measure of model fit/performance (0.0 – 1.0)
Coefficient	Strength and type (+/-) of relationship between explanatory variable and dependent variable
Probability/robust probability	Small value (<0.01) indicates <1% chance of coefficient being essentially zero
Joint F-statistic	Significant <i>p</i> -value indicates overall model significance
Joint Wald statistic	Significant <i>p</i> -value indicates robust overall model significance
Koenker statistic	Significant <i>p</i> -value indicates biased standard errors; use robust estimates
Jarque-Bera statistic	Significant <i>p</i> -value indicates residuals deviate from a normal distribution
Akaike's Information Criterion (AIC)	Measure of relative goodness of fit (the model with AIC >3 points lower is considered a better fit)

(Rosenstein et al., 2011b)

Table 2.

Candidate Explanatory Variables Used in Regression Modelling

Social Factors*	Physical Factors
Population count/density	Clinic is within 50m of major or arterial road
NZ Deprivation Index raw score	Clinic is located within 800m of city/city fringe/metropolitan/town centre (urban centre)**
Personal/household income	Distance from centre of Area Unit to centre of nearest urban centre.
Percent of population with post-secondary school qualification	Density of GP clinics within Area Unit (when musculoskeletal/osteopathic clinic is dependent variable)
Percent of population with access to a car/telecommunication	Density of musculoskeletal clinics within Area Unit (when GP clinic is dependent variable)
Percent of population on a means-tested benefit	Density of musculoskeletal clinics excluding osteopathic clinics within Area Unit (when osteopathic clinic is dependent variable)
Percent of population in full or part-time employment	
Percent of population employed in managerial/professional /trades/labouring roles	
Percent of population living in own home/rental	
Percent of population identifying as male/female	
Percent of population identifying as European/Maori/Asian/Pacific Islander	

* All data taken from 2006 New Zealand Census and aggregated at Area Unit level (Statistics New Zealand, n.d.-d)

**See Appendix C for urban centres' hierarchy key attributes

3.2.5 Geographically Weighted Regression

While OLS assumes that relationships are consistent geographically, in reality it is rare for a variable to be constant across a region (Mitchell, 2005). To account for this situation, ArcMap10's Geographically Weighted Regression (GWR) tool runs a regression for each feature (Area Unit) rather than the study area as a whole, allowing model coefficients to vary regionally (Brunsdon, Fotheringham, & Charlton, 1998; Mitchell, 2005). Previous accessibility-related applications of GWR include examination of geographical factors and problem gambling (Wheeler et al., 2006) and obesity (Schuurman et al., 2009). The GWR tool was used to provide a local model of the relationship between clinic density or count per Area Unit and the explanatory variables identified in the OLS model. Output consists of individual maps symbolising the local (Area Unit) R^2 and coefficients of each variable. GWR models were created using the same dependent and explanatory variables identified in the robust OLS models.

Chapter Four.

Results

4.1 Study area

Throughout this thesis, 'Auckland City' refers to the greater Auckland region (see inset, Figure 1), whereas 'urban Auckland' refers to the area inside the Auckland Council's official urban/rural boundary (P. Lee, personal communication, August 21, 2012), and 'central Auckland' refers to the central region within urban Auckland (see area shaded blue, Figure 1). The study area incorporated urban Auckland, with an area of 482.9 km² and a 2006 census population of 1,156,623 (Auckland Council, 2011).

Figure 1. Overview of Study Area. Inset: the Auckland region within New Zealand; top: areas within the Auckland region; bottom: urban Auckland.

4.2 Practice locations

A total of 968 practices were located in urban Auckland (see Figure 2). General practice (GP) showed the highest number of clinics, followed by physiotherapy, acupuncture, chiropractic and podiatry, and osteopathic clinics showed the lowest number (see Table 3).

Figure 2. Healthcare Clinic Locations in Urban Auckland. Left: GP clinics; right: musculoskeletal (osteopathic, chiropractic, physiotherapy, acupuncture, podiatry) clinics. One dot or cross represents at least one clinic.

Table 1.

Number of Clinics Located in Urban Auckland in May 2012

Modality	Data source	Number of clinics
Osteopathy	Osteopathic Council of New Zealand (www.osteopathiccouncil.org.nz)	72
Physiotherapy	Yellow Pages (yellow.co.nz) Localist (www.localist.co.nz) Finda (www.finda.co.nz)	243
Podiatry	Yellow Pages (yellow.co.nz) Localist (www.localist.co.nz) Finda (www.finda.co.nz)	76
Acupuncture	New Zealand Register of Acupuncturists (www.acupuncture.org.nz)	158
Chiropractic	New Zealand Chiropractic Board (www.chiropracticboard.org.nz)	109
General Practice	District Health Boards: Auckland, Counties Manukau, Waitakere HealthPoint (www.healthpoint.co.nz)	310
Total		968

4.3 Kernel Density

Visual inspection of the kernel density map (see Figure 3) describing the residential population/km² showed that the central business district (CBD) and city fringe had the largest area of high population density (4489 – 8573 residents/km²) within urban Auckland. The CBD and parts of the city fringe also appeared to have a higher number of healthcare clinics/km², compared to other areas, across all healthcare modalities measured. GP clinics had wide coverage over the entire area, with areas of increased clinic density loosely matching areas of increased resident population density, especially in Manukau, Papakura and central Auckland. Southern Manukau and Papakura had the largest area of low osteopathic clinic density, despite having large areas of high resident population density. Although North Shore appeared overall to have a lower residential population density than Manukau, North Shore had higher densities of osteopathic, physiotherapy, acupuncture and chiropractic clinics than southern Manukau, however eastern areas of Manukau appeared relatively well-covered by these modalities. The residential population density of Waitakere appeared similar to that of North Shore; however the overall density of osteopathic, physiotherapy, acupuncture and chiropractic clinics in Waitakere appeared to be less than that of North Shore.

Figure 3. Kernel Density Maps (clockwise from top left): meshblock residential population density (residents/km²), and density (clinics/km²) for osteopathic clinics, GP clinics, podiatry clinics, chiropractic clinics, acupuncture clinics, and physiotherapy clinics.

4.4 Hot spot analysis

The results of the Global Moran's I tool run at incremental distances showed clustering peaks at 3400 m for osteopathic, physiotherapy, podiatry and chiropractic clinics, 3800 m for acupuncture clinics, 2800 m for GP clinics and 4200 m for aggregated musculoskeletal clinics (see Appendix B). Accordingly, the respective Getis-Ord G_i^* calculations incorporated these measurements as radii.

The Getis-Ord G_i^* analysis showed definite hot spots (symbolised by red) and cold spots (symbolised by blue) of clinic densities in the study area (see Figure 4). Central Auckland is a consistent hot spot in each analysis. Smaller hot spots were seen in North Shore predominantly for osteopathic, acupuncture, physiotherapy and aggregated musculoskeletal clinics, and also GP and chiropractic clinics although to a much smaller extent. GP is the only modality to show hot spots in Manukau and Papakura. Physiotherapy, acupuncture and aggregated musculoskeletal clinics show cold spots in Waitakere and Manukau.

Figure 4. Getis-Ord Gi* Analysis of Musculoskeletal and GP Clinic Density per Meshblock in Urban Auckland

4.5 Cluster and outlier analysis

Results of the LMI analysis are presented in the form of cluster/outlier types (COType) (see Figure 5), with map colours symbolising a significant ($p < 0.05$) cluster of high I values (HH), cluster of low I values (LL), outlier in which a high I value is surrounded primarily by low I values (HL), and outlier in which a low I value is surrounded primarily by high I values (LH) (Mitchell, 2005). For all modalities, the HH types occurred within the central city hot spot previously identified in the Getis-Ord Gi* analysis, although these areas were interspersed with LH areas, which is considered to weaken evidence of clustering (Schuurman et al., 2009). Despite the Getis-Ord Gi* analysis of aggregated musculoskeletal clinics showing large cold spots in Waitakere, Manukau and Papakura, LMI analysis of aggregated clinics showed HL areas in Waitakere and Papakura, rather than the LL areas which may be considered analogous to cold spots. However, these HL areas were not in exactly the same location as the cold spots. In addition, analysis of individual modalities showed Waitakere had HL areas of osteopathic, physiotherapy and chiropractic clinics, whilst Manukau and Papakura had HL areas of podiatry and physiotherapy clinics. Individual Area Units throughout the majority of each study area showed no significant variation from their adjacent Area Units.

Figure 5. Anselin Local Moran's I Analysis of Clinic Density Per Area Unit.

4.6 Ordinary Least Squares

OLS results are summarised in Tables 2, 3 and 4. Due to wide variation in the geographical size of the Area Units across the study area, measurement of clinic density per Area Unit provided a more relevant OLS calculation than clinic count per Area Unit. Exploratory analysis of osteopathic and GP clinic density per Area Unit against a number of candidate explanatory variables (see Table 1) yielded robust multivariate models. The Koenker statistic was significant in each model, indicating the presence of non-stationarity between dependent and explanatory variables, and requiring the use of the robust probability statistics (adjusted R^2) (Rosenshein et al., 2011b). The adjusted R^2 was 0.71 for osteopathic clinics, 0.81 for GP clinics and 0.91 for aggregated musculoskeletal clinics, and all explanatory variables included had a robust p -value of <0.10 . Consistent across all three models were two clinic proximity explanatory variables: Proximity to a Major/Arterial Road (osteopathic: $r = 0.02$, GP: $r = 0.04$, musculoskeletal: $r = 0.82$) and to an Urban Centre (osteopathic: $r = 0.05$, GP: $r = 0.03$, musculoskeletal: $r = 0.28$). Population Density showed a very small yet significant positive correlation ($r < 0.01$) with osteopathic and GP clinic density. The NZDep2006 showed a very small negative correlation ($r = -0.02$) with osteopathic clinic density, indicating that as relative socioeconomic deprivation increases, osteopathic clinic density decreases. An increase in osteopathic clinic density appeared correlated ($r = 0.01$) with an increase in the density of other musculoskeletal modality clinics in the same Area Unit. While the Percentage of the Population with Post-Secondary School Qualifications appeared to decrease as GP clinic density increases ($r = -0.06$), aggregated musculoskeletal clinic density appeared to have the opposite relationship to the Qualification variable ($r = 1.53$). Of the ethnic groups measured (European, Maori, Asian, Pacific Island), only European ethnicity appeared to have a significant positive relationship ($r = 0.76$) to musculoskeletal clinic numbers. The Variance Inflation Factor for each explanatory variable (<7.5) indicated an absence of multicollinearity between variables, and is therefore not reported here. The Jarque-Bera statistic for each model attained statistical significance ($p < 0.05$), requiring analysis of residuals with the Global Moran's I statistic to detect spatial autocorrelation. The resulting Global Moran's I values and z-scores indicated in all cases that residuals were not clustered, and thus that models were robust.

Table 4.

OLS Results for Osteopathic Clinic Density Per Area Unit. Table shows adjusted R^2 , explanatory variable coefficients, summary statistics and analysis of residuals for spatial autocorrelation.

	Explanatory variable coefficients
Adjusted R^2	0.71
Population density	<0.01*
NZDep2006 raw score	-0.02**
Clinic is within 30 metres of a major/arterial road	0.02**
Clinic is within 800 metres of an urban centre	0.05*
Density of musculoskeletal clinics (not including osteopathic clinics) in Area Unit	0.01***
Summary statistics	
Koenker	72.44*
Joint F	155.45*
Joint Wald	122.08*
Jarque-Bera	3987.06*
Global Moran's i	0.05
z-score	1.39

* = Robust $p < 0.001$; ** = robust $p < 0.05$; *** = robust $p < 0.10$

All population data taken from results of the 2006 New Zealand Census and aggregated at Area Unit level (Statistics New Zealand, n.d.-d).

Table 5.

OLS Results for GP Clinic Density Per Area Unit. Table shows adjusted R^2 , explanatory variable coefficients, summary statistics and analysis of residuals for spatial autocorrelation.

	Explanatory Variable Coefficients
Adjusted R^2	0.81
Population density	<0.01*
Percent of population aged 18-64 with post-secondary school qualifications	-0.06**
Clinic is within 30 metres of a major/arterial road	0.04*
Clinic is within 800 metres of an urban centre	0.03*
Density of all musculoskeletal clinics in Area Unit	0.12*
Summary statistics	
Koenker	50.52*
Joint F	257.74*
Joint Wald	630.89*
Jarque-Bera	416.52*
Global Moran's i	-0.01
z-score	0.98

* = Robust $p < 0.001$; ** = robust $p < 0.05$; *** = robust $p < 0.10$

All population data taken from results of the 2006 New Zealand Census and aggregated at Area Unit level (Statistics New Zealand, n.d.-d).

Table 6.

OLS Results for Musculoskeletal Clinic Count Per Area Unit. Table shows adjusted R^2 , variable coefficients, summary statistics and analysis of residuals for spatial autocorrelation.

	Explanatory Variable Coefficients
Adjusted R^2	0.91
Percent of population aged 18-64 with post-secondary school qualifications	1.53**
Average personal income of residents aged 18 - 64	<-0.01**
Percent of population identifying as European	0.76**
Clinic is within 30 metres of a major/arterial road	0.82*
Clinic is within 800 metres of an urban centre	0.28**
Summary statistics	
Koenker	35.12*
Joint F	620.05*
Joint Wald	1664.53*
Jarque-Bera	1408.83*
Global Moran's i	0.03
z-score	1.64***

* = Robust $p < 0.001$; ** = robust $p < 0.05$; *** = robust $p < 0.10$

All population data taken from results of the 2006 New Zealand Census and aggregated at Area Unit level (Statistics New Zealand, n.d.-d).

4.7 Geographically Weighted Regression

4.7.1 Osteopathic clinic density per Area Unit

The GWR model representing osteopathic clinic density per Area Unit (adjusted $R^2 = 0.72$) had a slightly higher adjusted R^2 than the comparative OLS model (adjusted $R^2 = 0.71$). However, the Akaike's Information Criterion (AIC) value of the GWR model (-1471.64) versus the OLS model (-1469.32) showed a difference of only -2.32, which did not reach the threshold of -3 required to indicate better goodness of fit (Mitchell, 2005). Therefore the local model did not perform significantly better than the global model and consequently is not reported here.

4.7.2 GP clinic density per Area Unit

Summary statistics from the GWR model representing GP clinic density per Area Unit (adjusted $R^2 = 0.84$, AIC = -1064) appeared to indicate increased goodness of fit when related to the comparative OLS results (adjusted $R^2 = 0.81$, AIC = -1030). However, when the GWR model was checked for spatial autocorrelation of residuals using the Global Moran's I tool, the z-score of -2.08 ($p = 0.04$) indicated a lack of normal distribution of the residuals and a biased model, and was therefore not further explored.

4.7.3 Musculoskeletal clinic count per Area Unit

The GWR model representing musculoskeletal clinic count per Area Unit (adjusted $R^2 = 0.93$) performed better than the OLS model (adjusted $R^2 = 0.90$) and the difference between the AIC values (GWR = 647; OLS = 722) confirmed that the GWR model had a relatively better goodness of fit. The Global Moran's I (GMI = -0.01, $z = -.03$, $p = 0.72$) calculation indicated a normal and random distribution of residuals.

The adjusted R^2 varied from 0.89 in the northern part of the study area to 0.95 in the southern part. The Percent European coefficient exhibited the greatest variability, running from a positive to a negative sign in a north to south direction. The coefficient for the Urban Centres variable was weakest in North Shore and Rodney and stronger in southern regions, while the inverse is true for the Major Roads variable. The Income variable was very weak throughout the study area. Central Auckland, Papakura and parts of Manukau showed the weakest coefficients for the Percent Qualified variable.

Figure 6. GWR Coefficient Maps for Musculoskeletal Clinic Count Per Area Unit. Clockwise from top left: Local R^2 = local adjusted R^2 (overall goodness of fit of the multivariate regression model); European percent = proportion (%) of population identifying as European; Qualified = proportion (%) of population with post-secondary education; Income = average personal income; Major road = clinic is located within 30 m of major/arterial road; Urban centre = clinic is located within 800 m of an urban centre.

Chapter Five.

Discussion

The focus of this study was on osteopathic clinics, with the inclusion of comparable privately-run musculoskeletal clinics to provide context, and GP clinics for comparison to publicly-funded primary care facilities. The first aim of this research was to determine the extent to which the geographic distribution of musculoskeletal clinics, particularly osteopathic, compared to GP clinics varies across urban Auckland. Kernel density, G_i^* and LMI analyses were conducted to create maps allowing visualisation of spatial patterns. The results of these spatial pattern analyses showed substantial variability in the geographic distribution of all healthcare modalities examined, and a particular contrast between the predominantly privately-funded musculoskeletal clinics and the predominantly publicly-funded GP clinics.

5.1 Spatial pattern analyses

Consistent throughout the kernel density, G_i^* and LMI analyses was the observation that clinics from all modalities were clustered in the CBD and city fringe areas. The geographical concentration of related businesses has been observed in many different environments (Melo, Graham, & Noland, 2009), leading to development of the theory of 'agglomeration economies' to explain this phenomenon (Moomaw, 1988). Agglomeration economies are commonly described in two ways: urbanisation economies and localisation economies. Urbanisation economies refer to the advantages of scale that are experienced by all businesses in an urban area, with such advantages including a varied workforce, developed infrastructure, high levels of business services and interactions and a large local market (Moomaw, 1988). Localisation economies occur when similar businesses cluster together geographically, with benefits experienced from this arrangement including the ability to participate in industry-specific knowledge exchanges (Moomaw, 1988).

The Auckland CBD is New Zealand's major business and commercial centre, with a high density residential population and many thousands of people commuting into the area daily (Statistics New Zealand, n.d.-b). These attributes are typical of an area that can be characterised as having an urbanisation economy (Meyer, 2008). The CBD clinic clustering pattern shown in the kernel density, G_i^* and LMI analyses conducted here therefore suggest

that these businesses are ideally located to enjoy the advantages of an urbanisation economy. Similar clustering patterns have previously been shown in the practice locations of CAM clinics in Canada (Meyer, 2008). Alongside the advantages of scale enjoyed by all businesses in the area, these location patterns have been theorised to be advantageous to the owners of healthcare businesses by providing a large potential patient base, alongside opportunities for conducting necessary business activities and developing strategic and professional alliances (Meyer, 2008).

Further to the benefits of an urbanisation economy, the concept of 'supplier induced demand' (SID) suggests that areas with increased healthcare practitioner density coincide with increased utilisation of healthcare services per head of population (Richardson & Peacock, 2006) and may allow practitioners to charge increased fees (Liu & Mills, 2007). SID suggests that new clinics may benefit from locating in areas already supplied with similar healthcare services, thus creating a pattern of supply and demand which is not geographically balanced. Much research has shown evidence of SID in conventional medicine (Léonard et al., 2009), and increased chiropractic supply has also been associated with increased chiropractic use (Whedon et al., 2012). However, analysis of SID requires measurement of both supply and demand, and therefore suggestion of the influence of SID in this study is only speculative.

Kernel density, Gi* and LMI analyses indicate that southern Manukau and Papakura had low to non-existent provision of osteopathic clinics. Previous research into the distribution of osteopathic practitioners in New Zealand showed a similar result, with Manukau having the lowest number of osteopaths per head of population in the Auckland city region (Adams, 2003). Manukau and Papakura have been shown to experience the highest levels of socioeconomic deprivation in Auckland city, with 38% of the combined resident population of these two areas living in the most deprived 20% of meshblocks (White et al., 2008). Osteopathic practitioners are often also proprietors, and like all businesses, are at least partially motivated by profit. As a result, areas with high levels of economic prosperity may provide better markets for CAM services which typically require out-of-pocket payments, while areas with low levels of economic prosperity may be less attractive to clinic owners. Where primarily privately-funded, market-driven healthcare resources are concerned, previous studies have shown that as economic prosperity increases, so does the likelihood

that the area will have a higher per capita level of privately-funded healthcare supply (Kruger et al., 2012; Meyer, 2009), and while the results of the analysis conducted here broadly indicate that the inverse may be also true in the case of osteopathic clinics, further research is required to determine if this is the case.

The results of the Gi* analysis may have been muted by the low number of clinics in some datasets. For example, modalities with the lowest numbers of clinics, such as osteopathy (n = 71) and podiatry (n = 76), showed little or no evidence of cold spots in the Gi* analysis, possibly because the low number of clinics across the entire study area created a mean density near zero, making it less likely even for areas with very low clinic density to have a z-score smaller than -1.65. Meanwhile, Gi* analysis of the largest dataset, aggregated musculoskeletal clinics (n = 658), showed large cold spots centred in Waitakere and Manukau. However, this finding may not be predictive of the clinic distribution pattern that would be seen if the number of clinics within each modality were to be increased to a much larger number, as there is no way of accurately predicting the spatial arrangement of future clinics.

The kernel density maps produced in this study show that GP clinic density appeared to loosely correspond to areas of increased population density in Manukau and Papakura, and Gi* analysis showed GP clinic density hot spots in these two regions. Given the relatively high levels of socioeconomic deprivation experienced by many residents in these regions (White et al., 2008), the correspondence of GP clinic density to population density in these areas may reflect the effects of government initiatives aimed to ensure healthcare access for the entire population. For example, under the NZ Health Strategy, funding for GP services is based on capitation payments dependent on the size, demographics and specific healthcare needs of the enrolled population (Ministry of Health, 2001). Although there is evidence to suggest that in New Zealand, more deprived areas of the country experience shorter travel times to reach GP clinics (J. Pearce et al., 2007), the analyses conducted in the current study are not suitable for making such comparisons. However, it can be noted that in contrast to the distribution of musculoskeletal clinics, GP clinic density appeared to correspond at least partially with population density across the study area, apparently regardless of the socioeconomic status of the local residents.

5.2 Regression analyses

The second aim of this study was to identify factors which may be related to variations in the spatial pattern of osteopathic, GP and aggregated musculoskeletal clinic locations. OLS analyses identified several physical and social environmental variables related to clinic locations, and GWR modelling was subsequently used to determine the extent to which the relationships between these variables varied across the study area. Two variables related to the physical environment were consistent across the three OLS models reported here: proximity to an urban centre and proximity to a major or arterial road.

The inclusion of the variable related to clinic location within 800 m of an urban centre within all three models both restates the potential influence of an urbanisation economy on clinic location and highlights the possible importance of the commuter population in the creation of a patient base. Within these urban centres there is generally a strong emphasis on employment, with employment : residential ratios ranging from 0.8 : 1 in town centres, 2 : 1 in the city fringe, 2.8 : 1 in metropolitan centres and 4 : 1 in the CBD (Auckland Council, 2012). The inclusion of this variable may also simply be a function of land zoning and the availability of suitable premises allowing business establishment in these areas.

Clinic location within 30m of a major or arterial road was another consistent variable in all three OLS models, with the GWR analysis showing that this relationship was strongest for musculoskeletal clinics on the North Shore. These findings highlight a key point about the character of urban Auckland. As a young and rapidly growing city, urban Auckland has developed into a collection of sprawling suburban and industrial tracts of land, interspersed with local business centres, and connected by high-volume motorways and arterial roads (McKinnon, 1997), and features such as these have been identified as favouring travel by private vehicle (Bell, Wilson, Bissonnette, & Shah, 2013). New Zealand has one of the highest rates of car ownership in the world (Ministry for the Environment, 2009), and Auckland City's vehicle ownership rate has been measured at 64 cars per 100 people (Ministry of Transport, 2013), suggesting that clinic location along a major or arterial road may increase the visibility of the clinic to the intra-city travelling population. Another previously identified benefit of clinic location on a main road is proximity to recognisable or familiar landmarks (Peachey, 2011), which may facilitate the transfer of easy driving instructions to patients. However, location on these roads may be a double-edged sword as

they are often prone to traffic congestion at various times of the day, which may increase the time required to travel to a clinic by car, complicate roadside parking, or disrupt traffic flow further as cars attempt to turn in or out of driveways.

A third physical environmental factor appeared to be significant in the OLS analysis of osteopathic clinic density. An increase in osteopathic clinic density appeared correlated with an increase in the density of other musculoskeletal modality clinics in the same Area Unit. Although this finding may be suggestive of evidence of a 'localisation economy' (Moomaw, 1988), in which healthcare businesses may benefit from being in close proximity to other similar businesses by virtue of increased patient referrals (Meyer, 2008), there is some evidence to indicate that referrals to osteopaths from practitioners of other musculoskeletal modalities are rare (Peachey, 2011). Nonetheless, osteopaths working within multimodal practices may have a different experience, with previous research indicating that CAM practitioners working in multimodal clinics perceive the ability to cross-refer patients as a benefit because of the resulting increase in the overall volume of patient visits to the clinic (Meyer, 2008). Additionally, patients have been shown to be more willing to travel further to reach multimodal CAM clinics due to the perception that they offer more treatment options and are cheaper than visiting a solo practitioner (Andrews, 2003). The prevalence of multimodal musculoskeletal healthcare clinics has not been measured here, but may be a factor behind the positive correlation between increased osteopathic clinic density and increased musculoskeletal clinic density. It is also possible that this finding is a non-causal relationship, in which the association comes about via the effect of other variables such as such as demographics and zoning characteristics.

While these physical environmental variables provide an outline of factors which may be related to clinic location, the demographic characteristics of the local residential population may also influence the type of business that is attracted into an area (Meyer, 2013). Although a variety of social aspects of the environment were included as candidate explanatory variables, only five variables were found to be significant across the three OLS models. These variables related to population density, the NZDep2006, educational qualifications, income and European ethnicity.

The correlation between population density and osteopathic and GP clinic density was statistically significant but extremely weak, and was not a significant explanatory variable for aggregated musculoskeletal clinic count. This finding is noteworthy when compared to the stronger positive correlation noted for clinic location within 800 m of an urban centre, as it suggests that proximity to high density settlements has less influence on clinic location than proximity to an urban centre. Similar findings were noted in a regression analysis of CAM office locations in Canada, in which the population density of a municipality was not linked with the location of any of the CAM modalities analysed, but being part of an urbanised environment was in all cases (Meyer, 2012). In light of these results, Meyer (2012) suggests that underserved peripheral communities may require strategies that offset the pull of larger urban areas, and the same may be true in the case of urban Auckland.

The correlation between socioeconomic deprivation and clinic density varied across the OLS models describing osteopathic and GP clinic density and musculoskeletal clinic count per Area Unit. Increasing levels of socioeconomic deprivation, as measured by the NZDep2006 (White et al., 2008), were shown to be weakly but significantly correlated with decreasing osteopathic clinic density, indicating that osteopathic clinics may have a tendency to be located in less deprived areas. Although the overall NZDep2006 was not significantly related to aggregated musculoskeletal clinic count, two disaggregated components of the NZDep2006 index appeared to be important: income and level of education. The variable related to education level showed a strong positive relationship with musculoskeletal clinic density. While education level is a less direct measure of wealth than personal income, a higher level of education is also associated with a lower level of socioeconomic deprivation (White et al., 2008). In contrast, average personal income showed a very weak yet significant negative correlation with musculoskeletal clinic density. This finding perhaps reflects an urban environment where the highest income areas are predominantly residential, and do not contain the type of commercial area where a musculoskeletal clinic may be likely to be located. Since both higher education level and personal income are associated with lower levels of socioeconomic deprivation (White et al., 2008), their contrasting relationships with musculoskeletal clinic density are surprising. Areas with higher population income and education level have previously been associated with higher

chiropractic clinic density in Canada, leading to the suggestion that consumer 'cost sensitivity' to chiropractic services may cause business owners to seek to situate clinics in wealthy areas (Meyer, 2012). The results presented here suggest that a similar process may be a factor in the location of musculoskeletal clinics in urban Auckland.

In contrast to the results of the osteopathic and musculoskeletal clinic regression analyses, OLS analysis indicated that GP clinic density appeared to increase as the percentage of the population with post-secondary school qualifications decreased. This result appears to concur with previous research indicating that the most deprived neighbourhoods in New Zealand experience the shortest travel times to reach GP clinics, in comparison to the least deprived neighbourhoods (J. Pearce et al., 2007). The combined results of the variables in the three OLS models presented here that relate to socioeconomic level suggest that GP clinics may be more geographically accessible in neighbourhoods with lower socioeconomic levels than osteopathic or musculoskeletal clinics.

The OLS analysis conducted here shows that an increase in aggregated musculoskeletal clinic count appears to be correlated with an increase in the percentage of the Area Unit population identifying as European, although GWR analysis shows that this relationship is variable across the study area, with the coefficient changing from positive to negative in a north-south direction. This finding suggests that the northern areas have higher clinic numbers where there are more Europeans (compared to non-Europeans) whereas in the southern area clinic numbers are actually higher where there are more non-Europeans (compared to Europeans). The reasons for this anomalous result are unclear, and interpretations are therefore speculative. Regression analyses indicate that clinic proximity to major roads and urban centres is also important, and it is possible that contrasting patterns of urban residential growth across the city have led to higher percentages of non-Europeans residing close to major roads and urban centres in southern Auckland, and the opposite situation in the north. Meyer's (2012) analysis of CAM clinic locations in Canada showed that increased CAM presence was associated with increasing proportions of visible ethnic minorities, which the author attributes to the 'big city' nature of the clinic locations observed in this study, and the attraction of small healthcare businesses to locations with a diverse market. The results of the GWR analysis conducted here suggest that a similar relationship may be in place in Manukau and Papakura, however the rest of the study area

appears to have a relationship between ethnicity and clinic presence that is inverse to that described by Meyer (2012). The partial disparity between the data related to ethnicity presented here and in Meyer's (2012) study is unsurprising considering that the two studies were conducted in different countries, each with a unique ethnic history and composition.

5.3 Limitations of the study

The main focus of this study was on primary musculoskeletal healthcare resources legislated by the Health Practitioners Competence Assurance Act (HPCAA) (Ministry of Health, 2013) and/or eligible for funding from the Accident Compensation Corporation (ACC) (Accident Compensation Corporation, 2012). Secondary musculoskeletal healthcare facilities such as physiotherapy outpatient services were not measured, meaning areas which appear in this study to have low provision of musculoskeletal healthcare providers may experience some service provision from the publicly funded secondary healthcare system. Additionally, other types of privately funded musculoskeletal healthcare facilities may exist that are not included under the HPCAA or ACC and therefore have not been measured here, such as massage therapy and traditional Māori and Pacific Island healers.

The statistical techniques utilised in this study have some inherent limitations which may have an influence on their results. For example, within spatial analyses such as Gi* and LMI, features near the edge of the study area tend to have fewer neighbours than features in the centre of the study area, which can skew the results of distance-based statistics for these features as the values of the few neighbours will take on more importance in the calculation (Mitchell, 2005). Solutions such as creating a buffer within the border or assigning weights to features closer to the boundary (Mitchell, 2005) are not appropriate in this study area because much of the edge is coastline, and therefore there are no features outside the boundary.

Another potential limitation of the census data used in this study is its age. More recent census data is unavailable because the February 2011 Christchurch earthquake caused the scheduled 2011 census to be postponed until March 2013, with aggregated results to be published by 2014 (Statistics New Zealand, n.d.-a). However, research indicates that a reasonable degree of stability in the population may be expected between 2006 and 2012 (Tobias, Bhattacharya, & White, 2008). While more recent alternative data sources related

to individual census variables are available, the vast majority are limited by factors such as small sample sizes, or lack of geographic breakdown below national level (Statistics New Zealand, 2011a), circumscribing their utility in a project seeking to characterise accessibility across a city.

5.4 Further research

Although the results presented in this research show a clear imbalance in the geographic distribution of musculoskeletal healthcare clinics in urban Auckland, addressing this imbalance may not be as simple as placing new clinics in what currently appear to be underserved areas. The success and commercial viability of such healthcare clinics may be dependent on a number of physical and social aspects of the environment, some of which have been described here. However, even without government policies designed to ensure equitable access to healthcare resources for the entire population, the geographic diffusion of clinics throughout the urban environment may occur naturally. The diffusion of healthcare practices has been demonstrated amongst chiropractic and naturopathic practice locations in Canada. Williams (2000) found that within large metropolitan areas, the percentage growth in practitioner numbers far outstripped the percentage growth of the resident population, and there was also growth in the number of new practices in small cities, towns and villages. Williams (2000) suggests that a potential factor behind the growth of practices outside of large centres may be that the large cities were reaching market saturation, prompting practitioners to establish new practices in smaller centres.

Future research may address the extent to which musculoskeletal practice location diffusion occurs in urban Auckland. Such research may be especially pertinent in light of the recent development initiatives that have been planned for Auckland. For example, the Auckland Council's 'Auckland Plan' includes the Southern Initiative, in which regulatory and planning conditions are to be developed to encourage business investment in southern Auckland and growth of the infrastructure required to support business development (Auckland Council, 2012). Additionally, the Southern Initiative includes measures specifically directed at increasing the proportion of the southern Auckland population completing educational qualifications (Auckland Council, 2012). The success of such initiatives in areas that currently appear to have low numbers of musculoskeletal clinics may provide the physical

and social environmental conditions to attract the development of new healthcare clinics, thus encouraging the process of diffusion throughout the urban area.

Comparative analysis of other urban areas in New Zealand and other countries with a similar healthcare structure may determine whether the patterns noted in this study are applicable in the wider national or international context. Should areas with certain characteristics be shown to consistently have higher or lower densities of osteopathic, or other musculoskeletal, clinics, strategies can be developed to provide services that are accessible for people living or working in areas with low provision of osteopathic clinics.

Because GIS enables the integration of a large amount of data from many sources, there is scope for future GIS-based research to incorporate other aspects of accessibility into similar spatial analyses. For example, data regarding the opening hours and number of practitioners working at each clinic could be added to a GIS analysis to provide an overview of functional accessibility alongside geographic.

GIS could be used to study the effect of increasing clinic accessibility for certain demographic groups. For example, the recent development of 'vocational scopes of practice' by the OCNZ (Osteopathic Council New Zealand, 2013) includes a gerontology scope of practice. Following the work of Carlson et al. (2011), there is potential for GIS to be used to first identify areas with high densities of older adults, and then strategically place clinics specialising in gerontology so that they are easily accessible to people in these areas. The use of this strategy in the selection of a site for a community-based fall prevention program for older adults resulted in participation levels exceeding the goals of the programme (Carlson et al., 2011).

5.5 Conclusion

The results of this study suggest that the geographical distribution of musculoskeletal healthcare clinics in urban Auckland is unbalanced, with central Auckland consistently containing higher than average clinic densities of all modalities examined. In comparison, GP clinics appear to be more evenly spread across the study area. Regression analysis identified a number of physical and social environmental factors that appear to be correlated with clinic location, including proximity to major roads and urban centres, and residential socioeconomic status and ethnicity. These results may help to inform the development of strategies to improve the accessibility of musculoskeletal healthcare services for people living or working in areas with low provision of musculoskeletal clinics. Further research is required to explore the extent to which the patterns noted in this study are applicable in the wider national or international context.

Chapter 6.

References

- Accident Compensation Corporation. (2012). What support can I get? Retrieved from <http://www.acc.co.nz/making-a-claim/what-support-can-i-get/WCM001816>
- Adams, B. J. (2003). *The geographic distribution of osteopaths in New Zealand: Implications for the osteopathic profession*. (Unpublished master's thesis), Unitec Institute of Technology, Auckland, New Zealand.
- Aguilar, G. D., & Farnworth, M. J. (2013). Distribution characteristics of unmanaged cat colonies over a 20 year period in Auckland, New Zealand. *Applied Geography*, 37(0), 160-167. doi: <http://dx.doi.org/10.1016/j.apgeog.2012.11.009>
- Algert, S. J., Agrawal, A., & Lewis, D. S. (2006). Disparities in access to fresh produce in low-income neighborhoods in Los Angeles. *American Journal of Preventive Medicine*, 30(5), 365-370. doi: <http://dx.doi.org/10.1016/j.amepre.2006.01.009>
- Andrews, G. J. (2003). Placing the consumption of private complementary medicine: everyday geographies of older peoples' use. *Health and Place*, 9(4), 337-349.
- Anselin, L. (1995). Local indicators of spatial association—LISA. *Geographical Analysis*, 27(2), 93-115.
- Auckland Council. (2011). Population density: Are we talking about the same thing? *Monitoring Research Quarterly*, 4(1), 4. Retrieved from <http://www.aucklandcouncil.govt.nz/EN/planspoliciesprojects/reports/technicalpublications/Documents/mrq20110303.pdf>
- Auckland Council. (2012). *The Auckland Plan*. Auckland: Auckland Council.
- Auckland Council. (2013). Auckland Council GIS Viewer. Retrieved from <http://maps.aucklandcouncil.govt.nz/aucklandcouncilviewer/>
- Bagg, W., Dare, A. J., O'Connor, B. J., Poole, P., Reid, J. J., Rudland, J., . . . Wilkinson, T. J. (2010). Setting up new learning environments in regional and rural areas. *The New Zealand Medical Journal*, 123(1312), 83.
- Bell, S., Wilson, K., Bissonnette, L., & Shah, T. (2013). Access to primary health care: does neighborhood of residence matter? *Annals of the Association of American Geographers*, 103(1), 85-105. doi: 10.1080/00045608.2012.685050
- Bishop, F. L., & Lewith, G. (2010). Who uses CAM? A narrative review of demographic characteristics and health factors associated with CAM use. *Evidence-Based Complementary and Alternative Medicine*, 7(1), 11-28.

- Brabyn, L., & Gower, P. (2004). Comparing Three GIS Techniques for Modelling Geographical Access to General Practitioners. *Cartographica*, 39(2), 41-49.
- Brunsdon, C., Fotheringham, S., & Charlton, M. (1998). Geographically weighted regression--modelling spatial non-stationarity. *Journal of the Royal Statistical Society: Series D (The Statistician)*, 47(3), 431.
- Bryman, A. (2008). *Social research methods* (3 ed.). New York: Oxford University Press Inc.
- Carlson, T., York, S., & Primomo, J. (2011). The utilization of geographic information systems to create a site selection strategy to disseminate an older adult fall prevention program. *Social Science Journal*, 48(1), 159. doi: 10.1016/j.soscij.2010.09.002
- Corbetta, P. (2003). *Social research: theory, methods and techniques*. London: SAGE Publications Ltd.
- Coulter, I. D., Hurwitz, E. L., Adams, A. H., Genovese, B. J., Hays, R., & Shekelle, P. G. (2002). Patients using chiropractors in North America: who are they, and why are they in chiropractic care? *Spine*, 27(3), 291.
- Culliton, P. D. (1997). *Current utilization of acupuncture by United States patients*. Paper presented at the National Institute of Health Consensus Development Conference on Acupuncture, Bethesda, Maryland, USA.
- Cumming, J., Stillman, S., Liang, Y., Poland, M., & Hannis, G. (2010). The determinants of GP visits in New Zealand. *Australian and New Zealand Journal of Public Health*, 34(5), 451-457. doi: 10.1111/j.1753-6405.2010.00589.x
- Day, P. L., & Pearce, J. (2011). Obesity-promoting food environments and the spatial clustering of food outlets around schools. *American Journal of Preventive Medicine*, 40(2), 113-121.
- Esri. (2012). ArcGIS Desktop. Retrieved from <http://help.arcgis.com/en/arcgisdesktop/10.0/help/index.html#//005p00000011000000>
- Goodyear-Smith, F., & Janes, R. (2008). New Zealand rural primary health care workforce in 2005: more than just a doctor shortage. *Australian Journal of Rural Health*, 16(1), 40-46.
- Gosden, T., Bowler, I., & Sutton, M. (2000). How do general practitioners choose their practice? Preferences for practice and job characteristics. *Journal of Health Services Research and Policy*, 5(4), 208-213.
- Hart, J. T. (2000). Commentary: Three decades of the inverse care law. *BMJ: British Medical Journal (International Edition)*, 320(7226), 18.

- Hawthorne, T. L., & Kwan, M.-P. (2012). Using GIS and perceived distance to understand the unequal geographies of healthcare in lower-income urban neighbourhoods. *Geographical Journal*, 178(1), 18-30. doi: 10.1111/j.1475-4959.2011.00411.x
- Health Workforce Advisory Committee. (2003). *The New Zealand Health Workforce Future Directions – Recommendations to the Minister of Health 2003*. Wellington: Health Workforce Advisory Committee. Retrieved from www.hwac.govt.nz
- Hensher, D. A. (2001). The valuation of commuter travel time savings for car drivers: evaluating alternative model specifications. *Transportation*, 28(2), 101-118.
- Hiscock, R., Pearce, J., Blakely, T., & Witten, K. (2008). Is neighborhood access to health care provision associated with individual-level utilization and satisfaction? *Health Services Research*, 43(6), 2183-2200. doi: 10.1111/j.1475-6773.2008.00877.x
- Holdsworth, L. K., Webster, V. S., & McFadyen, A. K. (2006). Are patients who refer themselves to physiotherapy different from those referred by GPs? Results of a national trial. *Physiotherapy*, 92(1), 26-33.
- Huang, B., Dignan, M., Han, D., & Johnson, O. (2009). Does distance matter? Distance to mammography facilities and stage at diagnosis of breast cancer in Kentucky. *The Journal Of Rural Health: Official Journal Of The American Rural Health Association And The National Rural Health Care Association*, 25(4), 366-371.
- Janes, R., Dowell, A., & Cormack, D. (2001). New Zealand rural general practitioners 1999 survey--part 1: an overview of the rural doctor workforce and their concerns. *The New Zealand Medical Journal*, 114(1143), 492-495.
- Koordinates. (2009). NZ Deprivation Index 2006. Retrieved from <http://koordinates.com/#/layer/1066-nz-deprivation-index-2006/>
- Kruger, E., Whyman, R., & Tennant, M. (2012). High-acuity GIS mapping of private practice dental services in New Zealand: does service match need? *International Dental Journal*, 62(2), 95-99. doi: 10.1111/j.1875-595X.2011.00096.x
- Land Information New Zealand. (2011). NZ Road Centre Line (Electoral). Retrieved from <http://data.linz.govt.nz/#/layer/818-nz-road-centre-line-electoral/>
- Léonard, C., Stordeur, S., & Roberfroid, D. (2009). Association between physician density and health care consumption: A systematic review of the evidence. *Health Policy*, 91(2), 121-134. doi: <http://dx.doi.org/10.1016/j.healthpol.2008.11.013>
- Liu, X., & Mills, A. (2007). Supplier-induced demand and unnecessary care. In A.S. Preker, L. Xingzhu, E.V. Velenyi, E. Baris & S. Trinquard (Eds.), *Public ends, private means: strategic purchasing of health services*. (pp. 279 - 310). Washington: The World Bank.

- Loughnan, M. E., Nicholls, N., & Tapper, N. J. (2008). Demographic, seasonal, and spatial differences in acute myocardial infarction admissions to hospital in Melbourne Australia. *International Journal of Health Geographics*, 7, 1-15. doi: 10.1186/1476-072x-7-42
- McKenzie, F., Ellison-Loschmann, L., & Jeffreys, M. (2010). Investigating reasons for socioeconomic inequalities in breast cancer survival in New Zealand. *Cancer Epidemiology*, 34(6), 702-708. doi: 10.1016/j.canep.2010.07.007
- McKinnon, M. (Ed.). (1997). *Cities and cars: The expansion of Auckland, 1940s to 1950s. New Zealand Historical Atlas*. Auckland: David Bateman in association with Historical Branch, Department of Internal Affairs.
- McLean, G., Sutton, M., & Guthrie, B. (2006). Deprivation and quality of primary care services: evidence for persistence of the inverse care law from the UK Quality and Outcomes Framework. *Journal of Epidemiology and Community Health*, 60(11), 917-922.
- Melo, P. C., Graham, D. J., & Noland, R. B. (2009). A meta-analysis of estimates of urban agglomeration economies. *Regional Science and Urban Economics*, 39(3), 332-342. doi: <http://dx.doi.org/10.1016/j.regsciurbeco.2008.12.002>
- Menz, H. B., Gill, T. K., Taylor, A. W., & Hill, C. L. (2008). Predictors of podiatry utilisation in Australia: the north west Adelaide health study. *Journal of Foot and Ankle Research*, 1(8).
- Mercer, S. W., & Watt, G. C. M. (2007). The inverse care law: clinical primary care encounters in deprived and affluent areas of Scotland. *Annals of Family Medicine*, 5(6), 503-510. doi: 10.1370/afm.778
- Meyer, S. P. (2008). The spatial pattern of complementary and alternative medical offices across Ontario and within intermediate-sized metropolitan areas. *Urban Geography*, 29(7), 662-682.
- Meyer, S. P. (2009). A geographic assessment of 'total' health care supply in Ontario: complementary and alternative medicine and conventional medicine. *The Canadian Geographer/Le Géographe canadien*, 54(1), 104-122.
- Meyer, S. P. (2012). Place-specific explanations for the geographic patterns of complementary and alternative practitioners: contrasting chiropractic, massage, holistic, acupuncture, naturopathic and homeopathic operations in Ontario. *International Journal of Business and Social Science*, 3(8).
- Meyer, S. P. (2013). Evaluating the geography and the visibility tendencies of acupuncture treatment locations in metropolitan Toronto. Retrieved from <http://dx.doi.org/10.5772.54599>

- Ministry for the Environment. (2009). Total distance travelled. Retrieved from <http://www.mfe.govt.nz/environmental-reporting/transport/vehicle-km-travelled/total-vkt/>
- Ministry of Health. (2001). *The primary health care strategy*. Wellington, New Zealand. Retrieved from <http://www.moh.govt.nz>
- Ministry of Health. (2008). *A portrait of health: Key results of the 2006/07 New Zealand health survey*. Wellington: Ministry of Health.
- Ministry of Health. (2013). About the Health Practitioners Competence Assurance Act. Retrieved from <http://www.health.govt.nz/our-work/regulation-health-and-disability-system/health-practitioners-competence-assurance-act/about-health-practitioners-competence-assurance-act>
- Ministry of Social Development. (2010). *2010 the social report*. Wellington: Ministry of Social Development. Retrieved from <http://socialreport.msd.govt.nz/>
- Ministry of Transport. (2013). TV035: Transport volume: Fleet information. Retrieved from <http://www.transport.govt.nz/ourwork/TMIF/Pages/TV035.aspx>
- Mitchell, A. (2005). *The ESRI guide to GIS analysis: Spatial measurements & statistics* (Vol. 2). Redlands, California: ESRI Press.
- Moomaw, R. L. (1988). Agglomeration economies: localization or urbanization? *Urban Studies*, 25(2), 150-161.
- Nicholls. (2001). The work-force crisis, funding and bureaucracies. *New Zealand Medical Journal*, 114(1140), 417.
- Ord, J. K., & Getis, A. (1995). Local spatial autocorrelation statistics: Distributional issues and an application. *Geographical Analysis*, 27(4), 286-306. doi: 10.1111/j.1538-4632.1995.tb00912.x
- Orrock, P. J. (2009). Profile of members of the Australian Osteopathic Association: Part 2 - The patients. *International Journal of Osteopathic Medicine*, 12(4), 128.
- Osteopathic Council New Zealand. (2013). Osteopathic scope of practice schema and related qualifications prescribed by the Osteopathic Council. Retrieved from http://www.osteopathiccouncil.org.nz/images/stories/pdf/SOP_Final_Jan_13.pdf
- Osteopathic Council New Zealand. (n.d.). Looking for an Osteopath? Retrieved from http://www.osteopathiccouncil.org.nz/component/com_ocnzregister/Itemid,43/view,search/
- Parsons, J., & Marcer, N. (2006). *Osteopathy: Models for diagnosis, treatment and practice*. Philadelphia: Churchill Livingstone.

- Peachey, T. (2011). *Marketing in the osteopathic practice*. (Unpublished master's thesis), UNITEC Institute of Technology, Auckland.
- Pearce, J., Day, P., & Witten, K. (2008). Neighbourhood provision of food and alcohol retailing and social deprivation in urban New Zealand. *Urban Policy & Research*, 26(2), 213-227. doi: 10.1080/08111140701697610
- Pearce, J., & Dorling, D. (2006). Increasing geographical inequalities in health in New Zealand, 1980-2001. *International Journal of Epidemiology*, 35(3), 597-603.
- Pearce, J., Witten, K., & Bartie, P. (2006). Neighbourhoods and health: a GIS approach to measuring community resource accessibility. *Journal of Epidemiology and Community Health*, 60(5), 389-395.
- Pearce, J., Witten, K., Hiscock, R., & Blakely, T. (2007). Are socially disadvantaged neighbourhoods deprived of health-related community resources? *International Journal of Epidemiology*, 36(2), 348-355.
- Pearce, N., Dryson, E., Feyer, A., Gander, P., McCracken, S., & Wagstaff, M. (2004). The burden of occupational disease and injury in New Zealand: Report to the associate minister of labour. *National Occupational Health and Safety Advisory Committee*, Wellington.
- Pledger, M. J., Cumming, J. N., & Burnette, M. (2010). Health service use amongst users of complementary and alternative medicine. *The New Zealand Medical Journal*, 123(1312), 26-35.
- Richardson, J. R. J., & Peacock, S. J. (2006). Supplier-induced demand: reconsidering the theories and new Australian evidence. *Applied Health Economics and Health Policy*, 5(2), 87-98.
- Roemer, M. I. (1961). Bed supply and hospital utilisation: a national experiment. *Hospitals Journal of American Health Affairs*, 35, pp. 988-993.
- Rosenshein, L., Scott, L., & Pratt, M. (2011a). Exploratory Regression: A tool for modeling complex phenomena. *ArcUser* (Vol. Winter 2011).
- Rosenshein, L., Scott, L., & Pratt, M. (2011b). Finding a meaningful model. *ArcUser*, Winter. Retrieved from <http://www.esri.com/news/arcuser/0111/files/findmodel.pdf>
- Schneider, A. (2013). GPS visualizer. Retrieved from <http://www.gpsvisualizer.com/>
- Schuurman, N., Peters, P. A., & Oliver, L. N. (2009). Are obesity and physical activity clustered? A spatial analysis linked to residential density. *Obesity (19307381)*, 17(12), 2202-2209.

- Silverman, B. W. (1986). *Density estimation for statistics and data analysis*. New York: Chapman and Hall.
- Smith, B., Muma, R., Burks, L., & Muck Lavoie, M. (2012). Factors that influence physician assistant choice of practice location. *JAAPA: Journal of the American Academy of Physician Assistants*, 25(3), 46-51.
- Statistics New Zealand. (2011a). Alternative sources of data for 2011 census variables. Retrieved from <http://www.stats.govt.nz/Census/2011-census/alternative-data-sources.aspx>
- Statistics New Zealand. (2011b). Area unit - Statistics New Zealand. Retrieved from http://www.stats.govt.nz/surveys_and_methods/methods/classifications-and-standards/classification-related-stats-standards/area-unit/classification-and-coding-process.aspx
- Statistics New Zealand. (2012a). 1.5 millionth Aucklanders could be born today. Retrieved from http://www.stats.govt.nz/browse_for_stats/Corporate/Corporate/CorporateCommunications_MR1Feb12.aspx
- Statistics New Zealand. (2012b). *Subnational population estimates: At 30 June 2012*. Wellington: Statistics New Zealand. Retrieved from <http://www.stats.govt.nz/~media/Statistics/Browse%20for%20stats/SubnationalPopulationEstimates/HOTPYe30Jun12/SubnationalPopulationEstimatesYe30Jun12HOTP.pdf>
- Statistics New Zealand. (n.d.-a). About 2013 census. Retrieved from <http://www.stats.govt.nz/Census/about-2013-census.aspx>
- Statistics New Zealand. (n.d.-b). Commuting patterns in New Zealand: 1996 - 2006. Retrieved from http://www.stats.govt.nz/browse_for_stats/people_and_communities/Geographic-areas/commuting-patterns-in-nz-1996-2006/commuting-patterns-in-auckland.aspx
- Statistics New Zealand. (n.d.-c). Meshblock - Statistics New Zealand. Retrieved from http://www.stats.govt.nz/surveys_and_methods/methods/classifications-and-standards/classification-related-stats-standards/meshblock/definition.aspx
- Statistics New Zealand. (n.d.-d). Meshblock dataset - Statistics New Zealand. Retrieved from <http://www.stats.govt.nz/Census/2006CensusHomePage/MeshblockDataset.aspx>
- Taylor, W., Smeets, L., Hall, J., & McPherson, K. (2004). The burden of rheumatic disorders in general practice: consultation rates for rheumatic disease and the relationship to age, ethnicity, and small-area deprivation. *The New Zealand Medical Journal*, 117(1203), U1098-U1098.

- Tobias, M., Bhattacharya, A., & White, P. (2008). Cross classification of the New Zealand population by ethnicity and deprivation: trends from 1996 to 2006. *Australian and New Zealand Journal of Public Health*, 32(5), 431-436.
- Tobias, M., & Jit, C. (2003). Monitoring health inequalities: life expectancy and small area deprivation in New Zealand. *Population Health Metrics*, 1, 2-11.
- Whedon, J. M., Song, Y., Davis, M. A., & Lurie, J. D. (2012). Use of chiropractic spinal manipulation in older adults is strongly correlated with supply. *Spine*, 37(20), 1771-1777.
- Wheeler, B. W., Rigby, J. E., & Huriwai, T. (2006). Pokies and poverty: problem gambling risk factor geography in New Zealand. *Health and Place*, 12(1), 86-96.
- White, P., Gunston, J., Salmond, C., Atkinson, J., & Crampton, P. (2008). *Atlas of socioeconomic deprivation in New Zealand NZDep2006*. Wellington: Ministry of Health.
- Williams, A. M. (2000). The diffusion of alternative health care: a Canadian case study of chiropractic and naturopathic practices. *The Canadian Geographer/Le Géographe canadien*, 44(2), 152-166.
- World Health Organisation. (1978). Primary health care. *Report of the International Conference at Alma Alta, World Health Organisation, Geneva, Switzerland*.
- Yeshiwondim, A. K., Gopal, S., Hailemariam, A. T., Dengela, D. O., & Patel, H. P. (2009). Spatial analysis of malaria incidence at the village level in areas with unstable transmission in Ethiopia. *International Journal of Health Geographics*, 8, 1-11. doi: 10.1186/1476-072x-8-5
- Zhang, P., Wong, D. W., So, B. K. L., & Lin, H. (2012). An exploratory spatial analysis of western medical services in Republican Beijing. *Applied Geography*, 32(2), 556-565. doi: 10.1016/j.apgeog.2011.07.003

Chapter 7.

Appendices

Appendix A

Description of the Nine Variables, in Decreasing Importance, Used to Construct the New Zealand Index of Deprivation 2006.

Deprivation Domain	Census Variables
Income	Aged 18-64 years receiving a means-tested benefit
Income	Living in households with equivalised income below an income threshold
Owned home	Not living in own home
Support	Aged under 65 years living in a single-parent family
Employment	Aged 18-64 years and unemployed
Qualifications	Aged 18-64 years and without any qualifications
Living space	Living in households below an equivalised bedroom occupancy threshold
Communication	With no access to a telephone
Transport	With no access to a car

Table source: (White et al., 2008)

Appendix B

Global Moran's i Statistic Z-score for Clinic Density at Different Distance Thresholds.

Distance	GP z-score	Osteo z-score	Physio z-score	Podiatry z-score	Chiro z-score	Acupuncture z-score	Msk clinics z-score
2600m	2.76	4.29	8.60	2.37	11.35	6.31	18.64
2800m	2.91	3.96	8.26	3.15	11.32	6.98	19.63
3000m	2.90	4.15	8.67	3.15	10.86	7.95	20.07
3200m	2.75	4.25	9.35	3.30	10.82	8.38	20.59
3400m	2.69	4.37	9.63	4.02	10.93	8.59	21.48
3600m	2.50	4.21	9.36	3.93	10.63	9.12	21.55
3800m	2.08	3.70	9.24	3.62	11.16	9.64	21.72
4000m	2.02	4.00	9.12	3.47	11.48	9.59	21.82
4200m	2.22	3.95	9.08	3.31	11.75	10.07	25.36
4400m	2.62	4.47	9.76	3.99	12.78	10.34	25.22

Appendix C

Urban Centres' Hierarchy – Selected Key Attributes.

Centre	Economic	Social	Employment emphasis and Employment & Residential ratios
City Centre	24 Hours. Central banking, finance, insurance, and professional services. Other service and creative businesses. Head offices. Specialty retail. Activity precincts.	Civic headquarters. Major cultural / entertainment hub. Premier public spaces. Tertiary education.	Strongest employment focus. Median ratio 4:1
City fringe centres	Day and night activities. Diverse range of business activities. Small- and medium-sized businesses. Specialist precincts.	Local social infrastructure / entertainment. High quality public spaces.	Strong emphasis on employment in business precincts. Median ratio 2:1
Metropolitan centres	Day and night activities. Finance, insurance and professional services. Food and beverage. Comparison retail. Specialty retail. Regional offices.	Cultural / entertainment destination. High quality public spaces. Tertiary education.	Strong emphasis on employment. Median ratio 2.8:1
Town centres	Day and evening activities. Small- and medium-sized enterprises. Convenience and some specialty retail. Professional / personal services. Administration and support.	Community facilities. Local parks.	Balanced residential and employment. Median ratio 0.8:1
Local centres	Day and evening activities. Convenience retail (day to day). Small businesses.	Strong local and anchor point. Neighbourhood parks.	Residential focus with local services. Median ratio 0.5:1

Table modified from Auckland Council (2012, p. 262)

Appendix D

Scatterplot matrix showing relationships between dependent and explanatory variables used in OLS calculation for GP clinic density per Area Unit.

Appendix E

Scatterplot matrix showing relationships between dependent and explanatory variables used in OLS calculation for musculoskeletal clinic count per Area Unit.

Appendix F.

Scatterplot matrix showing relationships between dependent and explanatory variables used in OLS calculation for osteopathic clinic density per Area Unit.