Surveillance of health status and health risk: The future of data collection using the telephone in Australia

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ACRONYMS

AAPOR	American Association for Public Opinion Research
ABS	Australian Bureau of Statistics
AHS	Australian Health Survey
AWB	Australian Workplace Barometer
BMI	Body Mass Index
BRFSS	Behavioural Risk Factor Surveillance System
CATI	Computer Assisted Telephone Interviewing
CD	Collector Districts
CON	Contact rates
COOP	Cooperation rates
CVD	Cardiovascular disease
EWP	Electronic White Pages
HOS	Health Omnibus Survey
IRSD	Index of Relative Social Disadvantage
LA-RDD	List-assisted random digit dialling
MSE	Mean squared error
MXT	Web messaging platform
NCD	Non-communicable disease
NSW	New South Wales
OTT	Over-the-top
PAL	Primary approach letter
RCB	Relative coverage bias
RDD	Random digit dialling
REF	Refusal rates
RR	Response rates
SA	South Australia
SA1	Statistical Areas Level 1
SAMSS	South Australian Monitoring and Surveillance System
SDGs	Sustainable Development Goals
SEIFA	Socioeconomic Indexes for Areas
SES	Socioeconomic status
SMS	Short Message Service
SPSS	Statistical Package for Social Sciences
TSE	Total survey error
TRG	Technical Reference Group
VoIP	Voice over Internet Protocol
WHO	World Health Organization
UK	United Kingdom
US	United States of America

ABSTRACT

Epidemiologically-designed, continuous and effective chronic disease and behavioural risk factor surveillance systems provide scientific evidence at the local level to assist government, health professionals and administrators, to respond effectively in reducing the burden associated with non-communicable diseases (NCDs). Many monitoring and surveillance systems utilise the telephone as the method of choice in obtaining population data. However, the dramatic change in telecommunication usage, diminishing coverage of telephone sampling frames and declining participation in household surveys, has led to methodological and statistical challenges. This has led to the present study that explores these challenges through an established telephone data collection system in Australia, the South Australian Monitoring and Surveillance System (SAMSS). The aim of this research is to determine how telephone surveys in Australia can continue to be used to reliably collect representative information on health indicators and other related health issues by exploring alternative efficient and cost effective methods.

The first study, using face-to-face South Australian household survey data, found that using landline-based telephone number sampling frames excludes mobile-only households in Australia (27.8% of households in 2013). From 2006 to 2013, the proportion of mobile-only households has increased and this trend does not appear to be plateauing. This corresponds with the decrease in landline telephone coverage. Mobile-only households are demographically different in that respondents are more likely to be younger, never married and living in rented accommodation. By excluding this group, landline-based sampling frames may possibly produce biased health estimates for some health indicators, such as the proportion of people who are current smokers or who have a mental health condition. The second study found participation in SAMSS has decreased over a period of twelve years, with an 18.6% decrease in the response rate (from 68.9% in 2002 to 56.1% in 2014) and a 65.5% increase in the refusal rate. When demographic data are compared to Census data, SAMSS had a higher proportion of females, older people and people who rent, and these

groups are increasingly being over-represented over time. The result from these studies imply that a mobile telephone sample needs to be incorporated. Unfortunately, there is no complete mobile telephone sampling frame in Australia with a geographical marker and only 7% of the currently used nation-wide mobile telephone sampling frames are South Australian residents, making the sampling method uneconomic. This is compounded by lower participation in mobile telephone surveys compared to landline telephone surveys. Based on these methodological issues and corresponding with decline in participation, efficient methodological strategies need to be considered for smaller states like South Australia.

The last two studies present two different cost effective and efficient methodological techniques, to minimise bias in health estimates due to nonresponse and sample coverage, and to increase participation in mobile telephone surveys. One study used raked weighting methodology to overcome, to some extent, the nonresponse biases and sampling coverage problems associated with telephone surveys. By incorporating more sociodemographic variables such as renting and marital status, besides the usual age, sex and area of residence, health estimates such as the proportion of current smokers corresponds well with other more expensive face-to-face surveys. The last study used a simple novel technique of sending a text message to prospective survey respondents to improve participation.

This thesis has explored and shown, from a series of studies, that telephone surveys, with careful monitoring of procedures and use of innovative techniques and statistical methods, can still be used to collect and report information on chronic diseases and behavioural risk factors in Australia. The uniqueness of this body of works presents a detailed examination of the status of a current surveillance system by nonresponse rates, trends of nonresponse rates and coverage biases, and links this information to possible solutions to overcome nonresponse biases, with the aim of producing reliable and representative health estimates.

DECLARATION

I certify that this work contains no material which has been accepted for the award of any other degree or diploma in my name in any university of other tertiary institution and, to the best of my knowledge and belief, contains no material previously published or written by another person, except where due reference has been made in the text. In addition, I certify that no part of this work will, in the future be used in a submission in my name for any other degree or diploma in any university of other tertiary institution without the prior approval of the University of Adelaide and where applicable, any partner institution responsible for the joint award of this degree.

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PUBLICATIONS AND CONFERENCE PRESENTATION CONTRIBUTING TO THIS THESIS

Published

1. Dal Grande E, Chittleborough CR, Campostrini S, Taylor AW. Bias of health estimates obtained from chronic disease and risk factor surveillance systems using telephone population surveys in Australia. Results from a representative face-to-face survey in Australia from 2010 to 2013. BMC Medical Research Methodology, 2016.
[See Chapter 3 and Appendix 5]

2. Dal Grande E, Chittleborough CR, Campostrini S, Tucker G, Taylor AW. Health Estimates Using Survey Raked-Weighting Techniques in an Australian Population Health Surveillance System. American Journal of Epidemiology, 2015;182(6):544-556.
[See Chapter 5 and Appendix 5]

3. Dal Grande E, Chittleborough CR, Campostrini S, Dollard M, Taylor AW. Pre-Survey Text Messages (SMS) Improve Participation Rate in an Australian Mobile Telephone Survey: An Experimental Study. PLoS ONE, 2016;11(2):e0150231.
[See Chapter 6 and Appendix 5]

Submitted for Publication

4. Dal Grande E, Chittleborough CR, Campostrini S, Taylor AW. Does declining participation in household telephone surveys over the last 12 years indicate that telephone surveys are no longer representative?

Conference presentation

5. Dal Grande E, Taylor AW, Fullerton SP, Chittleborough CR, Campostrini S. Can telephone surveys be used for collecting health information in Australia? Population Health Congress. Adelaide, Australia; 10-12 September 2012.
[Poster, See Appendix 4]

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Chapter 1: Introduction

The growth of non-communicable diseases (NCDs) as an important priority area is mirrored around the world[1]. Increasing emphasis has been directed at reducing NCDs as a result of the high burden these diseases place on the general population and health systems. The shift in priority from communicable or infectious diseases to NCDs is mainly due to the ageing of the population, changing lifestyle behaviours, and improvements in the treatment and prevention of infectious diseases[2, 3]. Epidemiologically-designed, continuous and effective surveillance systems[4] are important tools in the fight against the increasing prevalence of NCDs. A well-designed surveillance system provides scientific evidence at the local level to assist government, health professionals and administrators to respond effectively in providing adequate resources to reduce the economic burden for government, health services and individuals.

Established chronic disease and behavioural risk factor surveillance systems around the world that rely on ongoing, high quality epidemiological population surveys have been shown to provide evidence on the magnitude of diseases and behavioural risk factors, and to track changes in prevalence estimates over time[5, 6]. In addition, these systems are important for developing and evaluating interventions and health promotion strategies[6, 7] aimed at improving the health status and wellbeing of individuals and populations[8-10]. In Australia, chronic disease and behavioural risk factor surveillance systems have been established in several states with ongoing commitment and resources by their state governments[11-13]. These systems are similar to each other such that they are ongoing, monthly, population-based telephone surveys collecting local information on chronic conditions, behavioural risk factors, mental health and wellbeing[5, 6, 11-17]. Notably, there are also methodological differences, but despite these difference, all of the systems are similarly challenged in providing unbiased estimates.

Population surveys conducted via the telephone have changed over the last 15 years in Australia and elsewhere, as have specific methodological issues related to chronic disease and behavioural risk factor surveillance systems. As technology has evolved, so have social structures and societal values, resulting

in communication behavioural changes which have impacted on epidemiological surveys, specifically telephone surveys[18]. Previously, telephones, computers and televisions were typically stand-alone and in a fixed position within the household. Nowadays, all of these devices are converging into a single portable telecommunication device usually belonging to one individual. These devices allow multiple ways to communicate via access to various media services and networks (fixed, mobile, or wi-fi). At the same time, the way people communicate using telecommunications has changed. Communication devices now allow the use of a variety of different platforms (for example telephone calls, emails, short messaging services (SMS)), and have changed how people seek information and how they use transaction services such as banking and finance. In addition, changes to communication options such as over-the-top (OTT) messaging services and social networks (iMessage, WhatsApp, Facebook Messenger, SnapChat)[19], have dramatically altered the communication and telecommunication environment.

These technological changes affecting all levels of society, and resultant behavioural changes in the use of these technologies, have had an impact on population surveys, in particular, telephone surveys. This has led to the present study of these changes, using an established data collection system in Australia, the South Australian Monitoring and Surveillance System (SAMSS)[11]. The aim of this research is to determine how telephone surveys can continue to be used to reliably collect representative information on health and other related issues, using a statistical method and surveying practice to compensate for two of the major concerns, non-coverage of the sampling frames and increased nonresponse. Within South Australia, with a relatively small population, there is a need to examine efficient and cost effective methodologies that can enable SAMSS to continue to produce reliable estimates.

This thesis by publication is divided into the following chapters. Chapter 2 provides the background literature relevant to the research and details the research questions. Chapters 3 to 6 include four manuscripts (three published, one submitted for publication) addressing these research questions. The first

study assesses the potential biases of selected health estimates in South Australia by examining the sampling frames that are currently used, and the impact of the increasing uptake of mobile telephones on population-based telephone surveys (Chapter 3). Chapter 4 explores nonresponse rate trends, including response, refusal, contact and cooperation rates, and the representativeness of SAMSS over the last 12 years. The next two chapters present possible solutions to overcoming the methodological issues found in the previous chapters. Chapter 5 examines a different statistical adjustment of survey weights by applying raked weighting methodology which incorporates a wider range of sociodemographic variables using an iterative proportional fitting process. Chapter 6 reports on an experimental study design that assesses the effectiveness of sending a SMS to a random sample of mobile telephone numbers prior to surveys to increase response rates. The final concluding chapter summarises the research results, discusses the contributions of this thesis to the broader literature on the methodological aspects associated with Australian chronic disease and behavioural risk factor surveillance systems, and the future of these surveillance systems. This final chapter also outline the limitations of this study and provide direction for future studies.

Chapter 2:   Background

2.1   Non-communicable diseases

Non-communicable diseases (NCDs) are now of major importance in Australia and other developed countries[1, 20]. With improvements in the treatment and prevention of communicable or infectious diseases in Australia, the burden and impact of chronic diseases has risen to be a major health concern, mainly due to the ageing of the population and changing lifestyle behaviours[1,3]. NCDs impact on the quality of life of the individuals with the disease(s), as well as their families or carers, and have a significant financial burden on the broader health system, especially in regard to providing treatment[21-23].

In 2012, the World Health Organization (WHO) reported that nearly two thirds (63%) of all deaths worldwide were due to NCDs, specifically, cardiovascular diseases (CVD) (45%), cancers (22%), chronic respiratory diseases (11%) and diabetes (3.4%)[1, 24, 25]. In Australia, the figure is much higher, with 91% of all deaths due to NCDs[24]. There are many chronic conditions in Australia and worldwide that are not major causes of death but which have a significant impact on the day-to-day living, general well-being and disability of individuals[26]. Mental health disorders, in particular depression, are one of the leading causes of disability burden in Australia. The lifetime prevalence of mental health disorders of Australians aged 16 to 85 years is 45% and one in five experience more than one mental disorder over a 12 month period[27-29]. Musculoskeletal disorders, including arthritis, osteoporosis and back pain, are significant causes of disability in Australia and are largely responsible for not only individual pain and disability but are also a significant burden on health services[26]. Many people have more than one condition (15.7% of adults have at least two or more chronic diseases in South Australia[30]) and these people have a greater impact on health services in terms of frequency and length of time spent in hospital, total health care costs and medication use[31]. Preventing and managing NCDs is important to individuals, society and governments.

2.2   The role of behavioural risk factors in the development of NCDs

Chronic diseases are often caused by a complex interaction of preventable behavioural factors such as smoking, high levels of alcohol consumption, insufficient physical activity and poor nutrition[8].   Chronic diseases are prolonged in duration, often have long periods before the disease is detected, and are rarely completely cured. Individuals can have risk factors associated with the disease for many years before the development of the disease[23]. The increase in these risk factors in Australia and similar countries is the result of a combination of societal changes in terms of cultural, environmental and behavioural factors[9, 32].   Individual behavioural risk factors (alcohol use, tobacco use, high blood pressure, overweight or obesity, high cholesterol, high blood glucose, low fruit and vegetable intake, and physical inactivity), or a combination of risk factors, are responsible for 61% of CVD deaths globally. Tobacco use alone is also responsible for 71% of lung cancers[3, 33].   When combined with tobacco use, excessive alcohol consumption, physical inactivity and obesity increases the risk of CVD, diabetes, and many forms of cancer[34]. Also of concern is that obesity rates have increased in the developed world over the past few decades[35]. Obesity is associated with increases in blood pressure, cholesterol levels and resistance to insulin. These behavioural risk factors are now linked to a range of other chronic conditions such as arthritis, osteoporosis and asthma, all of which increase the burden on the health system, and result in lower quality of life for individuals[3, 21, 34].

Other broader not individually focused factors, that contribute to poor health have been acknowledged in the recent WHO's Millennium Development Goals to Sustainable Development Goals (SDGs)[1]. Some of the actions aimed at reducing the impact of these factors include ending poverty and hunger; providing equitable quality education;   increasing the availability of water; combating climate change; working on the conservation and sustainability of oceans, seas and marine resources; creating safe, resilient and sustainability cities and human settlements;   and developing sustainable and inclusive economic growth, full and productive employment. While these factors are

critically important, the focus of this thesis will be on the traditional behavioural related risk factors.

2.3   Evidence for prevention

Due to the rising prevalence of chronic diseases and behavioural risk factors, policy makers and public health practitioners need reliable, representative and timely population data to plan, implement and monitor public health programs, allowing appropriate allocation of preventative programs and health services based on local requirements and limited resources[36, 37]. Policy makers, service providers and health promoters need this information, particularly since the economic downturn has had an impact on funding for health services, and governments at national and state levels are facing budget constraints. Yet the general community has an expectation of accessing high quality and affordable health care and treatment, and expects governments to make informed and strategic policy decisions to finance them appropriately[21, 37]. In a recent WHO document, *Global Action Plan for the Prevention and Control of Noncommunicable Diseases 2013-2020*, one of the six objectives was to "monitor the trend and determinants of non-communicable disease and evaluate progress in their prevention and control"[4]. This objective consists of 25 global indicators and nine voluntary global targets. As part of the action items, the document proposed to integrate a surveillance system or undertake periodic data collection on behavioural and metabolic risk factors. In Australia, national documents have outlined a range of indicators to monitor the progress of selected chronic diseases and their associated risk factors[38].

Chronic diseases and behavioural risk factors are distributed unequally across socioeconomic groups according to employment status, occupation type, education level and income; and sociodemographic characteristics such as sex, age, marital status, area of residence, ethnicity and Aboriginal status[22, 38]. These variations add to the challenges of public health efforts to reduce the impact of chronic diseases in terms of quality of life, and health service use and costs[32, 39]. Information is needed to track the overall changing trends (i.e.

increases or decreases in prevalence or severity) in chronic diseases and associated behavioural risk factors, by socioeconomic or sociodemographic characteristics in order to improve preventive and control strategies[6, 9, 32]. For example, at the population level, we need to know who smokes, how many cigarettes are being smoked and how often, but also how these estimates change over time. Continuous population-level surveillance systems can provide this evidence. Surveillance data can demonstrate if the prevalence of risky behaviours has decreased because of a health promotion campaign or the introduction of a new legislation, and if the decrease has been experienced by all sociodemographic groups. These data provide important scientific evidence for developing and evaluating disease prevention or interventions, and health promotion strategies[6, 7].

2.4   The use of surveillance in public health

Public health surveillance is described as "the epidemiological foundation for modern public health"[40-42]. As defined by the WHO, "public health surveillance is the continuous, systematic collection, analysis and interpretation of health-related data needed for the planning, implementation and evaluation of public health practice"[43].

The key aspect of a chronic disease and behavioural risk factor surveillance system is the routine tracking of these topics over time[6, 10]. The method of data collection needs to be quick and efficient, with smaller samples at more frequent time periods i.e. "skimming the surface" compared to point-in-time data collections which are usually less frequent, with longer periods of data collection and larger samples. Surveillance systems should focus on "high level" national and state indicators. In contrast, comparable point-in-time surveys can focus on more in-depth research associated with chronic disease or behaviours. A surveillance system should be relatively inexpensive, flexible, have established methods for standardised questions and procedures, and provide trend data for monitoring[44]. Some of the fundamental components of a chronic disease or behavioural risk factor surveillance system are listed as follows[6]:

1. The system is continuous in data collection, analysis and use, i.e. on a highly regular basis, such as daily or monthly - not yearly.
2. The system is population-based.
3. The system does not focus on the individual(s). The aim of a surveillance system is to monitor changes at the population level, not changes in individuals.
4. A "social survey" is the instrument for the collection of data, i.e. it is not administrative. The instrument (survey) consists of questions that relate to behaviours associated with chronic diseases or health status and the survey (questions) is the same one used every time period.
5. 'Time" is a critical variable, i.e. data are collected over time as close to continuously as possible.
6. Focuses on changing over time, not at a point in time.
7. Technical and structural aspects are critical.
8. The system is based on an underlying theory.

It is essential that the surveillance system is dynamic; all the components are occurring at the same time and continuously changing over time with the acquisition of new knowledge from within and from other systems[6, 45]. For example, the questions may need to be refined or questions added about emerging population issues. The data collection may change because of methodological issues due to declining response rates or inadequate sampling frames. This ability to adapt or refine is the advantage of a surveillance system over an occasional or less frequent survey. A surveillance system can be a learning system (Figure 2.1). New knowledge is gained via a continuous upward spiral beginning with data collection and revolving through the other components: data analysis, interpretation and data use.

Figure 2.1: The 'spiral' of the surveillance system
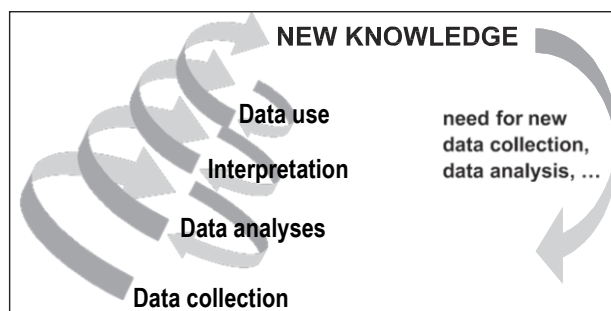
Source: Campostrini & McQueen 2005[45]

There are numerous well established chronic disease and behavioural risk factor surveillance systems in Australia[11-13] and internationally[46-48]. Various systems follow the key features of a surveillance system: population based, continuous monthly social surveys, with independent samples drawn at each time period. Many of these surveillance systems use telephone surveys based on Computer Assisted Telephone Interviewing (CATI) technology since it has been demonstrated as a cost-effective and timely method of collecting health information. There is no overarching single chronic disease and behavioural risk factor surveillance system in Australia. Rather, systems are operated, funded and resourced separately within states and territories, and address local priority areas as well as national interests. Of the eight states and territories in Australia, only three have continuous surveillance systems (New South Wales, South Australia and Western Australia)[11-13]. Victoria[49] and Queensland[50] have annual repeated surveys but the remaining jurisdictions, Australian Capital Territory, Tasmania and the Northern Territory, do not have a system and rely on periodic national surveys or the infrastructure from the other states. States developed their continuous chronic disease and behavioural risk factor surveillance system or an annual health survey for local needs, and thus each has slightly different methodologies best suited to the local population, resources and available funds.

2.5 Telephone interviewing as a data collection tool

Over the last 20 years, telephone surveys have become a standard and accepted method of collecting health information in Australia[5, 11-17]. Since the mid 1990s, over 90% of the Australian population had fixed telephone landlines, thus providing sufficient coverage for telephone surveys[51-54]. Subsequently, telephone surveys were established a cost-effective and timely method of collecting health information[12, 13, 55-57]. Telephone surveys have provided greater standardisation of survey administration through closer supervision of interviewers compared to traditional face-to-face surveys of interviewing a respondent's household. In addition, telephone surveys have the ability to reach a large number of individuals, especially in rural or remote communities of Australia[58, 59]. They have the added advantages of accessing people in secured buildings or behind locked gates (a safer method for both interviewers and participants), interviews can be conducted in different languages with access to interpreters from a central location, and telephone surveys easily screen the general population for special groups of interest such as migrants or people with specific chronic diseases[59-62]. The telephone surveys utilise computers, where the questions appear on the monitor to be read out and the interviewers immediately enter the response. Skip patterns are executed according to the responses that are entered. Data can be made available for analyses at the end of the survey.   As such, telephone surveys are an ideal instrument for surveillance of chronic diseases and behavioural risk factors.

2.6 Issues with the telephone as a data collection tool

Probability-based sampling is considered the survey method of choice to produce non-biased estimates[18, 63-66] for many systems using face-to-face, telephone, mail and online surveys. Chronic disease and behavioural risk factor surveillance systems are usually designed using probability-based sampling methods that aim to achieve samples that accurately represents the population of interest.   These sampling techniques are scientifically-based and broadly include stratified, randomised, clustered and systematic sampling, or a combination of these[66]. Based on these techniques, when the "sampling units"

have a known probability of selection from a complete sampling frame, inferences on these probability-based samples can be generalised to the population as a whole[18, 65]. Thus the scientific principle of sampling should therefore provide reliable information. However, all surveys are subject to errors such as non-coverage, nonresponse, sampling and measurement error[67, 68]. As previously highlighted, the properties of CATI surveys have been influenced by technological and societal changes[17, 69] and this have contributed to biases and increased costs[18, 62, 70].

A Total Survey Error (TSE) theoretical framework has been developed to describe the statistical properties of estimates derived from population surveys in a way that addresses errors within the survey design. This has been developed in an attempt to balance costs and errors to maximise survey quality[68, 71, 72]. An example is shown Figure 2.2 where TSE is split into two domains: sampling errors and non-sampling errors.

Figure 2.2: Total survey error and components
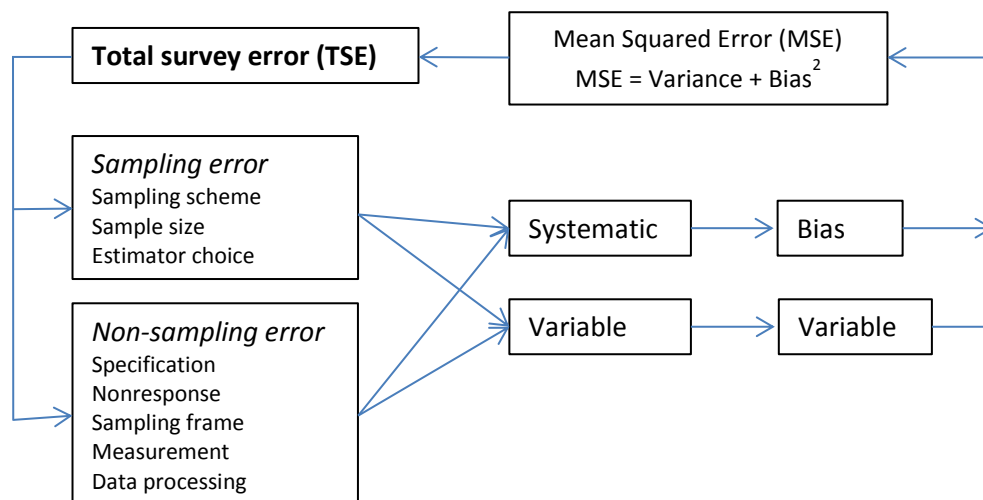
Source: Biemer 2010[68]

Sampling errors can be attributed to the sampling scheme such as stratified, multistage or clustered, sample size or the choice of estimator such as level of post-stratification. Non-sampling errors in surveys are mainly due to

specification (concept), nonresponse, non-coverage, measurement (incorrect information), and data processing[64, 68, 71, 72].

The following sections will cover two components of survey errors that are common within chronic disease and behavioural risk factor surveillance systems: nonresponse and sampling frames (non-coverage). The other areas are beyond the scope of this thesis.

2.6.1 Nonresponse bias in telephone surveys

High quality surveys are dependent on the adequate representation of data from the population of interest. Nonresponse occurs when the respondent or sampled unit does not participate in a survey (unit nonresponse) or answer a particular question (item nonresponse)[71, 73]. Nonresponse is problematic in household surveys, including chronic disease and behavioural risk factor surveillance systems, because they are reliant on the voluntary participation of the selected respondent. Unit nonresponse, the failure to obtain an interview from all the eligible respondents in the sample[64, 71], is compounded by the fact that in Australia it is not possible to obtain any demographic or other information about the nonrespondents[74]. Unit nonresponse in telephone surveys is due to three main reasons: unable to establish contact with the selected respondent (noncontacts); refusal to participate; and unable to participate because of language problems, disabilities (e.g. hearing or mental) or health conditions (e.g. frailty)[71, 72, 74]. Nonresponse bias or error occurs when the estimates from the survey sample do not reflect the "status" or "opinions" of the population because of low participation, or there is an over or under-representation of some groups, for example, more older people and less younger people. When the aim of the study is to obtain prevalence estimates, nonresponse bias results in estimates that may not be representative of the population of interest. Therefore, nonresponse bias is a major concern for chronic disease and behavioural risk factor surveillance systems since the purpose is to monitor, over time, the prevalence of key health indicators in the population.

Response and nonresponse rates are often used to evaluate the performance of surveys[75]. It is well documented that nonresponse rates have been increasing for over 30 years[76-84], not only for telephone surveys but for population surveys of all modes (face-to-face, mail, online)[84, 85]. As a consequence, the cost of all survey modes including telephone surveys has increased[86]. The use of technology such as answering machines and caller ID has contributed to declines in response rates for telephone surveys due to privacy concerns, survey burden and the ability to screen calls[69, 87]. The community has become fatigued with market research and the intrusion into personal and family time such as at evening meal times. People are worried about invasion of their privacy and have developed a mistrust of unsolicited calls due to a range of issues including identity theft[86, 88, 89]. Both technological and societal changes have contributed to an alarming increase in refusal and noncontact rates[69, 90].

As refusals and noncontact are the biggest contributors to nonresponse, it is important that nonresponse biases are continuously assessed to determine if adjustments, such as weighting or imputation, are needed to reduce discrepancies between the survey data and the population of interest[90, 91]. For many chronic disease and behavioural risk factor surveillance systems in Australia, demographic information cannot be ascertained for nonrespondents (noncontacts or refusals) which is why the response and nonresponse rates[75] have been used as key indicators of representativeness and survey quality[92, 93]. It has been commonly thought that the higher the response rate, the better the quality and hence representativeness of the survey data. However, it has been demonstrated that estimates from studies with lower response rates do not necessarily differ to studies with a higher response rate[82, 94, 95] and it has been argued that there is little relationship between nonresponse rates and nonresponse bias[82, 96]. It has been recommended that researchers look beyond using a single overall summarised measure as an indicator of survey quality and nonresponse bias[92, 97].

Alternative measures have been suggested when there is little information on the nonrespondents, but they are not as simple to calculate as response and nonresponse rates[97-100]. Other analytical techniques should be conducted to assess nonresponse bias [82, 92, 97, 98]. Halbesleben & Whitman[101] have proposed a framework in assessing nonresponse bias, as shown in Figure 2.3. This framework can guide researchers in the most appropriate assessment techniques to use.

Figure 2.3: Decision chart for nonresponse bias assessment
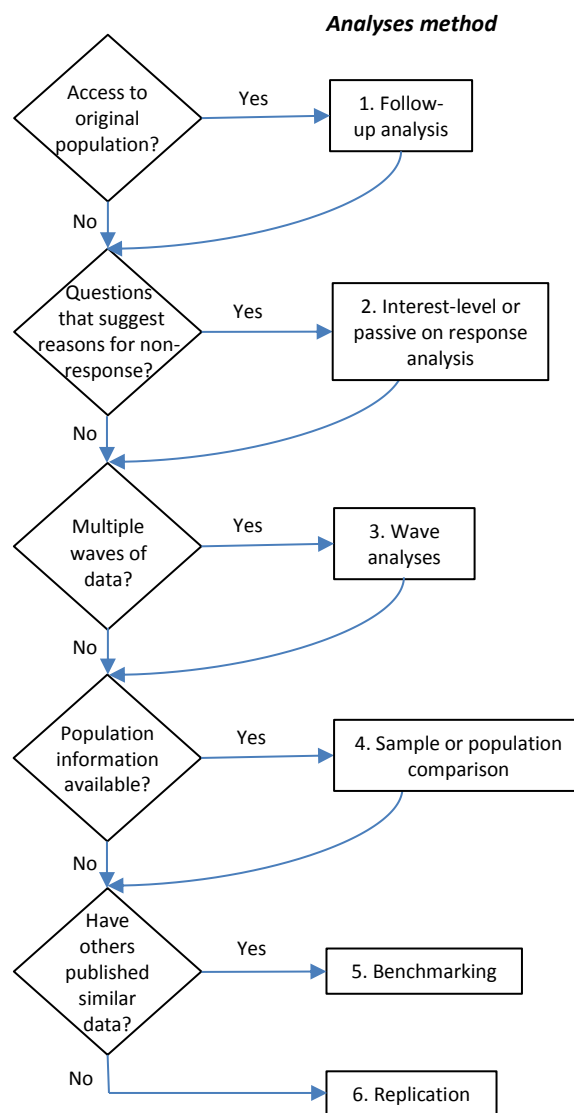
Source: Halbesleben & Whitman (2013) [101]

The decision chart is structured in the "order of how unlikely the research is to be able to answer yes" to questions regarding the sample. The first question asks about access to the original population, and occurs in situations such as research among hospital patients where (de-identified) information on basic sociodemographic, health status, and other hospital-related information can be obtained and compared. This is not the case for the sampling frames used in either landline or mobile telephone surveys. The second question examines either the nature of nonresponse or level of interest in participating in the survey. Researchers can examine (where possible) respondents who actively choose not to participate and respondents who passively do not respond, for example, those who forget to complete the survey. The third question asks whether information is known at any stage such as at different waves of data collection. As stated previously, most chronic disease and behavioural risk factor surveillance systems in Australia do not have any available demographic information on nonrespondents, and as such, analyses methods 4, 5 or 6 (as noted in Figure 2.3) are commonly used to assess nonresponse biases[51, 55, 102, 103].

2.6.2   Telephone-based sampling frames in Australia

Another source of sampling error is due to coverage[71]. Survey coverage and the adequacy of the sampling frame(s) are increasing concerns for those involved in epidemiologically-sound telephone surveys[17, 51, 52, 62, 104, 105]. Over the last 10 years, studies have examined the differences between various landline sampling frames used in Australia: mainly listed, known as Electronic White Pages (EWP), and a list of randomly generated landline telephone numbers, referred to as random digit dialling (RDD)[51, 52, 104, 106]. EWP consists of listed landline telephone numbers that includes name and address details with a low proportion of mobile telephone numbers (approximately 7.3% of mobile telephone owners in South Australia have their mobile telephone number listed[107]). These telephone numbers are centrally located and routinely listed in the EWP regardless of the telecommunication carrier.

Households can opt, at a cost, to not have their telephone number listed in the EWP (silent numbers). RDD methods in Australia are constructed based on the prefixes of the telephone numbers found in the EWP to generate a sampling frame. RDD sampling frames include silent numbers. This method is referred to as list-assisted RDD (LA-RDD). Generally, various studies have found that no one landline sampling frame is clearly superior[107, 108] as they all generally under-represent men, younger people, people living in low socioeconomic status (SES) areas, and people who live in rented accommodation.

2.6.3 Changes in telecommunications and impact on telephone surveys

Similar to international trends, the last decade has seen Australian telecommunications rapidly change with the emergence of new technologies and a move away from traditional landline telephones to flexible communications[17, 62, 107, 109]. The uptake of mobile telephones, Voice over Internet Protocol (VoIP), and portable technologies such as mobile telephone and wireless internet have been increasing, which has had a negative impact on telephone surveys and some sampling methodologies. In Australia, 86% of households in 2010 had a landline telephone connection, with older people more likely to maintain their landline connections compared to young people[107, 110]. The use of VoIP services in homes to make telephone calls was around 16% in Australia with the highest uptake among people aged between 25 and 44 years[110]. As of June 2010, 14% of households in Australia had a mobile telephone but no landline telephone, with the highest proportion amongst the younger age groups and people in low SES households[110]. The dramatic increase in mobile-only households has occurred both internationally and in Australia[17, 62, 110-112]. In a recent South Australian face-to-face survey, results showed that the proportion of mobile-only households had increased from 1% in 1999 to 17% in 2010, and to 22% in 2011[109]. Mobile-only households were more likely to be younger (36.4% of those aged 15 to 29 years, 33.5% of those aged 30 to 44 years), never married (31.1%), separated or divorced (30.5%), unemployed (35.2%), and to reside in low and lowest SES areas (28.6%)[109]. These issues highlight that a sample of mobile-only

households should be included in telephone surveys, to ensure that reliable and representativeness estimates are produced. Neither of the traditionally used EWP or RDD sample frames are based on mobile telephone numbers.

Like most countries around the world[62, 113], Australia does not have a sampling frame of mobile telephones with a geographical location such as postcode or state. In contrast, the majority of landline telephone numbers are listed in the EWP and the prefix of the telephone numbers is geographically based. These prefixes are used to generate RDD samples in an attempt to obtain unlisted (or silent) landline telephone numbers[103]. Mobile telephones are the opposite: they are rarely listed (7.3% of mobile telephone owners in South Australia are listed[107]) and the number structure does not provide any details of geographical location, hence making it difficult to generate a sampling frame similar to current cost effective RDD landline methods.

As stated previously, the states and territories in Australia that have a continuous or annual repeated survey operate independently with various methodologies. Each jurisdiction uses different methodologies based on their population size, priority areas, the amount of funding received from state and national public funds (this amount is largely dependent on the population size in each state), and different sociodemographic profiles. The total population of Australia was 22 million in 2014, with a median age of 38.3 years[114]. The majority of Australia's population are living in the eastern states with New South Wales having the largest population (32.0%) followed by Victoria (24.9%) and Queensland (20.1%). The other states and territories are comparatively much smaller in population size: 11.0% of Australians live in Western Australia, 7.2% in South Australia, 2.2% in Tasmania, 1.6% in the Australian Capital Territory and 1.0% in the Northern Territory. Like most developed countries, Australia's population is ageing as a result of sustained low fertility and increasing life expectancy. This has resulted in proportionally fewer children (under 15 years of age) in the population and a proportionally larger increase in those aged 65 and over. According to the 2014 population estimates[114], Tasmania has the oldest median age of all the states and

territories (41.6 years), followed by South Australia (39.9 years). The Northern Territory has the youngest median age (31.8 years), followed by the Australian Capital Territory (34.9 years). These population differences, together with differing priorities and resources, jurisdictions have developed different survey methodologies; one method may be applicable or affordable in one jurisdiction but may not be suited to another. This is why jurisdictions with small populations like South Australia and Western Australia have different sampling methodologies and use different sampling frames to New South Wales or Victoria.

It should be noted that for some states, a continuous or annual surveillance system is not feasible because of the sociodemographic profile. In the Northern Territory, which has a large Aboriginal or Torres Strait Islander population residing in rural or remote areas, landline-based telephone surveys are not possible. Therefore other methods that adhere to cultural sensitivity and respect are required[115].

2.7 Research undertaken regarding potential solutions

The challenge for telephone surveys and surveillance systems in Australia is to ensure the methodology is effective and efficient in obtaining and providing representative and reliable population data. The systems need to adapt to the changing telecommunication technologies, usage patterns of these new technologies and participation in surveys in our society. To address these issues, investigating cost effective strategies to maintain high quality data for users (policy makers, service providers and health promoters) of these systems is required. Detailed below are three possible strategies that are explored in this thesis. It is acknowledged that research into many other avenues is possible.

2.7.1 Dual-frame sampling

Dual-frame sampling methods have been widely used as one solution to incorporate mobile-only households into telephone surveys[15, 62, 106, 108]. This involves two separate sampling frames: one based on landline telephone numbers and the other on mobile telephone numbers. A number of studies in Australia have investigated this method[103, 116]. Samples for these studies were obtained from a company named *Sampleworx* which provided a list of RDD landline and mobile telephone numbers. While RDD is based on a list-assisted methodology, the source of the mobile telephone frame is not detailed. Both studies showed an improvement in representativeness, in particular for men, the younger and middle age groups, and people who were never married[107, 109, 117]. However, the response rates achieved from both samples using RDD methodology were low: 35.0% for the landline frame and 31.5% for the mobile frame from the study conducted by Barr et al[103], and response rates of 22% from the landline frame and 13% from the mobile frame from the study conducted by Livingstone et al[116] and Barr et al[103] found the total average cost of the mobile frame was more than twice the cost of the landline frame. Interestingly, using RDD methodology in New South Wales, 7% of the initial mobile telephone sample (n=17534) resulted in an interview (n=1224) with 34% of the calls being ineligible since the mobile telephone was owned by people not living in New South Wales (n=5966). Penny et al[118] has reported that nearly 30% of mobile telephones are owned by people living in New South Wales, with 28% in Victoria and nearly 8% in South Australia. Examining the disposition codes from both studies highlighted that a large initial sample size was required to include respondents from mobile-only households in the targeted jurisdiction. A much larger sample would therefore be required for South Australian surveys where only 8% of mobile telephones are owned by South Australians. Hence, including mobile telephone numbers using these methods in a surveillance system in South Australia would be costly. As such, other methodological or statistical techniques need to be examined, developed and tested in the South Australian setting.

2.7.2   Use of specific mobile telephone technology

Mobile telephones, in particular smartphone technology, are becoming the most accessible form of communication worldwide, with SMS or text messaging becoming one of the most frequent forms of communicating. This is a further area of research covered within this thesis. Although, mobile telephone numbers are increasingly being included in chronic disease and behavioural risk factor surveillance systems sampling frames, via RDD mobile telephone-based methods[103, 116] or via the small proportion in EWP samples[51, 52], this does not overcome the issue of higher nonresponse rates compared to landline telephone surveys[103, 106, 116, 119].

To maintain probability-based sampling techniques, many epidemiological studies employ a number of strategies to increase participation in telephone surveys including: primary approach letters; increasing the number of call attempts in an endeavour to obtain the hard-to-reach respondents; varying the calls during the time of the day and day of the week; increased training of the interviewers; saliency of the survey topic; promoting the credible source (government, hospital, university); and establishing the importance of the survey contents[64, 82, 120-123]. Some of these strategies developed to increase participation in traditional landline surveys over the last decade can be adapted for mobile telephone surveys. The value of incorporating SMS in chronic disease and behavioural risk factor surveillance systems is still in its infancy and has received little attention, although it is widely used in other arenas[124-129]. SMS has been used by many organisations for reminders for appointments, various public health interventions such as losing weight and smoking cessation, and chronic disease management[130-132]. These studies have demonstrated SMS is an accepted form of communication.

However, applying traditional landline telephone strategies to conduct a mobile telephone survey may not be straightforward. Firstly, mobile telephones are more than a single function of just communicating by voice; they have different integrated features, capabilities, platforms and functions of various quality. Secondly, they have the additional complexity of usage level and experiences

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with mobile telephones by the general population[129]. Notwithstanding, innovative methods exploiting SMS based on traditional strategies to increase participation should be evaluated.

2.7.3 Statistical techniques

Additional research in this thesis has been undertaken to assess the improvement in statistical methods that have been developed to address the telephone sampling coverage and declining response rates. One area of refinement that can be utilised to adjust for these concerns is *weighting*, a statistical technique used in most population surveys that ensures the representativeness of a population sample[66, 90, 91, 133]. The conventional weighting approach uses the *post-stratification* method to adjust the sample data by creating a cross-classification of the categorical control variables (e.g. age groups *x* sex *x* area of residence *x* marital status *x* income). However, in most surveys with small total sample sizes such as 1000 interviews, this is not feasible because of small cell sizes in the cross-tabulations. A technique has recently re-emerged[134], called *raked weights* or *raking*, which overcomes the conventional problem of small cell sizes by adjusting the sample data one variable at a time using an iterative proportional fitting process. This technique has existed since 1940[135] and has been used for many different situations[136-138] other than weighting. The term "raking" suggests an analogy of smoothing the soil in a garden plot by alternately working it back and forth with a rake in two perpendicular directions[134, 139]. Similar to current weighting procedures, raking adjusts the data so that groups which are under-represented in the sample can be accurately represented in the final dataset. In the United States (US), the Behavioural Risk Factor Surveillance System (BRFSS) uses raking to adjust by sex, age, race, education, telephone coverage and other key demographic variables. It has reported major differences between raking and traditional weighting estimates with measures of health risk and chronic diseases generally increasing, and measures of health access generally decreasing[15, 134, 140].

2.8 Research objectives and hypotheses

Based on the previous review of the literature and the issues facing chronic disease and behavioural risk factor surveillance systems in Australia, the overall aim of this thesis is to determine how telephone surveys in Australia can continue to be used to reliably collect representative information on health status and risky behaviours by exploring other statistical methods or surveying techniques.

The research questions for this thesis are then divided into two sections: one to describe the status of telephone surveys in Australia, and the second to investigate potential solutions in the Australian and South Australian context. The specific research questions are as follows:

1. What is the current status and biases of telephone survey methodology in Australia related to sampling frames and nonresponse biases?
2. Can methods such as raked weighting and innovative techniques such as using SMS be potential solutions to reducing bias in telephone survey sampling frames and nonresponse bias in Australia?

The hypotheses for the research are as follow:

H_1: There are differences in terms of sociodemographic, health status and health risk behaviours for people living in mobile only households compared to people living in landline and mobile households, or landline only households.

H_2: The declining response rates over the last 12 years have changed the representativeness of household (telephone) surveys.

H_3: Raked weighting statistical methodology will reduce the biases in health status and health risk behaviour estimates due to nonresponse and under-coverage.

H_4: Using text messages can increase participation in mobile telephone surveys in Australia.

This thesis by publication contains three peer-reviewed publications and a paper currently under peer-review. The following published manuscripts in

Chapters 3 to 6 have used a variety of data sources, and methods, and details of these are included within each manuscript.

2.9 Summary

Chronic disease and behavioural risk factor surveillance, with the ultimate aim of reducing the impact of chronic disease in the community, is an important tool for public health. Many monitoring and surveillance systems utilise the telephone as the method of choice in obtaining these data. Australian states like South Australia, with a relatively small population, receive lower Commonwealth funds compared to larger states, so there is a need to investigate efficient and cost effective methodologies and alternatives for use in respective chronic disease and behavioural risk factor monitoring and surveillance systems. With the dramatic changing pattern of telecommunication usage and declining response rates, monitoring of these issues, an assessment of the impact on household health surveys and the implications of the significant results on health policy is required. In an article in 2011, Groves[141 p870] highlighted that *"survey research is not dying; it is changing"* and until these problems are investigated in the Australian and South Australian context, the potential for bias due to under-coverage remains a real and growing threat.

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Chapter 3:   Publication - Bias of health estimates obtained from chronic disease and risk factor surveillance systems using telephone population surveys in Australia

3.1 Statement of Authorship

Title of Paper	Bias of health estimates obtained from chronic disease and risk factor surveillance systems using telephone population surveys in Australia: result from a representative face-to-face survey in Australia from 2010 to 2013
Publication Status	☑ Published ☐ Accepted for Publication ☐ Submitted for Publication ☐ Unpublished and Unsubmitted work written in manuscript style
Publication Details	BMC Medical Research Methodology, 2016; 16(1):1-13. DOI: 10.1186/s12874-016-0145-z

Name of Principal Author (Candidate)	Eleonora Dal Grande		
Contribution to the Paper	Participated in the design and co-ordination of the study, performed statistical analyses, and drafted and revised the manuscript.		
Overall percentage (%)	85%		
Certification:	This paper reports on original research I conducted during the period of my Higher Degree by Research candidature and is not subject to any obligations or contractual agreements with a third party that would constrain its inclusion in this thesis. I am the primary author of this paper.		
Signature		Date	15/6/2016

Name of Co-Author	Catherine R. Chittleborough		
Contribution to the Paper	Participated in the design and co-ordination of the study, advice on analyses, and was involved in the drafting and revising of the manuscript. I give permission for Eleonora Dal Grande to present this paper for examination towards the doctor of Philosophy.		
Signature		Date	6/6/2016

Name of Co-Author	Stefano Campostrini		
Contribution to the Paper	Participated in the design and co-ordination of the study, advice on analyses, and was involved in the drafting and revising of the manuscript. I give permission for Eleonora Dal Grande to present this paper for examination towards the doctor of Philosophy.		
Signature		Date	10/6/2016

Name of Co-Author	Anne W. Taylor		
Contribution to the Paper	Participated in the design and co-ordination of the study, advice on analyses, and was involved in the drafting and revising of the manuscript. I give permission for Eleonora Dal Grande to present this paper for examination towards the doctor of Philosophy.		
Signature		Date	15/6/2016

3.2 Abstract

Background: Emerging communication technologies have had an impact on population-based telephone surveys worldwide. Our objective was to examine the potential biases of health estimates in South Australia, a state of Australia, obtained via current landline telephone survey methodologies and to report on the impact of mobile-only household on household surveys.

Methods: Data from an annual multi-stage, systematic, clustered area, face-to-face population survey, Health Omnibus Survey (approximately 3000 interviews annually), included questions about telephone ownership to assess the population that were non-contactable by current telephone sampling methods (2006 to 2013). Univariable analyses (2010 to 2013) and trend analyses were conducted for sociodemographic and health indicator variables in relation to telephone status. Relative coverage biases (RCB) of two hypothetical telephone samples was undertaken by examining the prevalence estimates of health status and health risk behaviours (2010 to 2013): directory-listed numbers, consisting mainly of landline telephone numbers and a small proportion of mobile telephone numbers; and a random digit dialling (RDD) sample of landline telephone numbers which excludes mobile-only households.

Results: Telephone (landline and mobile) coverage in South Australia is very high (97%). Mobile telephone ownership increased slightly (7.4%), rising from 89.7% in 2006 to 96.3% in 2013; mobile-only households increased by 431% over the eight year period from 5.2% in 2006 to 27.6% in 2013. Only half of the households have either a mobile or landline number listed in the telephone directory. There were small differences in the prevalence estimates for current asthma, arthritis, diabetes and obesity between the hypothetical telephone samples and the overall sample. However, prevalence estimate for diabetes was slightly under-estimated (RCB value of -0.077) in 2013. Mixed RCB results were found for having a mental health condition for both telephone samples. Current smoking prevalence was lower for both hypothetical telephone samples in absolute differences and RCB values: -0.136% to -0.191 for RDD landline samples and -0.129% to -0.313 for directory-listed samples.

Conclusion: These findings suggest landline-based sampling frames used in Australia, when appropriately weighted, produce reliable representative

estimates for some health indicators but not for all. Researchers need to be aware of their limitations and potential biased estimates.

3.3 Background

Many established population-based, continuous chronic disease and behavioural risk factor surveillance systems worldwide utilise Computer Assisted Telephone Interviewing (CATI)[6, 9-13, 46-48]. Since the 1990s, CATI surveys have been seen as an ideal tool since they are effective, relatively inexpensive, flexible and timely[6, 10, 14, 17, 47, 142]. However, over the past 15 years vast changes have occurred in the telecommunication industry (mobile telephone and internet) and society's acceptance of, and engagement with, these new technologies[110, 143]. The new communication technologies have had an impact on population-based telephone surveys, specifically, the diminishing coverage of traditional sampling frames and declining response rates[17, 62] resulting in increased costs[86, 87] and potential bias in survey estimates[82, 144].

In the early 1990s, 95-97% of Australian households had a landline telephone connected[52] and response rates of around 70-80% were the norm[51-54, 105]. For population health surveys in Australia, two sampling methodologies were used: directory-listed telephone numbers, referred to as Electronic White Pages (EWP) and random digit dialling (RDD) of landline telephone numbers[12, 51, 52]; both methods having the ability to target geographical areas (state, suburbs or postcodes) which has contributed to the utility and efficiency of telephone surveys[107, 108]. EWP consists mainly of listed landline telephone numbers with name and address details for a household or business which the sampling frame can be easily stratified by state, suburb or postcode. EWP has mobile and Voice over Internet Protocol (VOIP) telephone numbers but only as a small proportion of the total sample. One drawback of EWP is that it does not include unlisted (silent) telephone number; that is, households which have opted, at a cost, to exclude their landline telephone number from the EWP. RDD methods have been developed to include silent landline telephone numbers based on the prefixes of the landline telephone numbers. Some of these methods use the

EWP, known as list-assisted RDD (LA-RDD), to make the sampling frame more efficient by removing blocks of numbers that have a high chance of not being connected or are assigned to large businesses[12, 145]. These RDD methods do not include mobile or VoIP telephone numbers. Since the turn of this century, there has been a trend of households moving away from traditional landline telephones with the emergence of mobile-only households[17, 62, 110, 112]. This is due to increasing portability, flexibility, affordability and broadening internet capability of mobile telephones including smartphones and other telecommunications, such as VoIP[17, 62, 107, 109, 146-148].

As a result of the increasing use of mobile telephones, conducting telephone surveys has become increasingly problematic in Australia and other countries [62, 113]. This is because of the difficulty in obtaining a representative sampling frame of mobile telephones numbers since are they are rarely listed (7.3% of mobile telephone owners in South Australia are listed[107]). Unlike the structure of landline telephone numbers, the Australian mobile numbers do not provide details of geographical location and the common methods used to generate a RDD sample of landline telephone numbers geographically are not applicable to mobile telephone numbers[103, 106]. In 2011-12, approximately 20% of households in Australia were mobile-only[109, 143], 34% of USA households in 2012 were mobile-only [146] with countries in Europe reporting 50-70%[148]. More notably, studies have found that mobile-only households are demographically different to traditional landline households: they are generally younger people, unrelated, never married, and socioeconomically disadvantaged[107, 146]. These issues suggest that by excluding mobile-only households biased estimates may be produced from chronic disease and behavioural risk factor surveillance systems.

This study presents the most up-to-date estimates available on the current status and possible sample biases of the current telephone survey methodology in South Australia, a state of Australia. Data from an annual representative face-to-face (non-telephone) population survey that included questions about telephone ownership were used to assess the population that were non-

contactable by current telephone sampling methods. This included both household landline and mobile telephone ownership and listings in the telephone directory. This study will 1) explore trends of landline and mobile telephone ownership between 2006 and 2013; 2) describe the sociodemographic characteristics of respondents living in mobile-only households between 2010 and 2013; and 3) investigate the coverage bias of the two telephone samples (directory-listed numbers (EWP), consisting mainly of landline telephone numbers and a small proportion of mobile and VoIP telephone numbers; and a RDD sample of landline telephone numbers which excludes mobile-only households) by examining the prevalence estimates of health status and health risk behaviours between 2010 and 2013. This is one of the few studies to assess the potential bias of health estimates due to coverage bias from telephone sampling frames in terms of health indicators and sociodemographics, using a unique data source with telecommunication information on people who would be excluded from the hypothetical telephone samples[107, 146]. This study uses relatively current data, which is important since telecommunications technologies have rapidly changed and evolved over the last 10 years, with increased uptake and saturation of mobile telephones and associated changes in the way people communicate[19]. Methodological studies therefore need to continually assess sample coverage and potential bias in health-related estimates[107].

3.4   Methods

3.4.1   Survey design and sample selection

The Health Omnibus Survey (HOS)[149, 150] is a multi-stage, systematic, clustered area sample of South Australian households where face-to-face interviews are conducted annually. The HOS sample includes households randomly selected from Australian Bureau of Statistics (ABS) collector districts (CDs) (2006 to 2012) and Statistical Areas Level 1 (SA1) (2013), from the metropolitan Adelaide area and country towns with a population of 1,000 people or more. Within each CD or SA1, a random starting point was selected and from this point 10 households were selected in a given direction with a fixed skip interval.

Hotels, motels, hospitals, hostels and other institutions were excluded from the sample. An approach letter and a brochure introducing the survey were sent to the selected household and the person aged 15 years or over, with the last birthday, was chosen for interview. The interviews were conducted in people's homes by trained interviewers. Up to six call back visits were made to chosen households to interview the selected person. There was no replacement for non-respondents and no incentive of any kind was offered. Approximately 3000 people participate annually, achieving a median response rate of 59.3% (range: 52% to 60%). The data are weighted by five year age groups, sex, and area (metropolitan Adelaide and rural/remote South Australia) to the most recent Census or Estimated Residential Population for South Australia and probability of selection within the household size to provide population estimates.

3.4.2 Household telecommunications ownership

Questions regarding telecommunications services in the household, specifically, landline telephone and mobile connections, were included in the 2006 to 2013 HOS. Mobile-only households were defined if the respondent had a mobile telephone with no working landline connection to the household. Landline connections did not include using VoIP connection or Skype for telephone calls. In addition, questions were asked regarding landlines and mobile telephones currently listed in the Australian White Pages. From these questions, household landline and mobile telecommunication status were determined by classifying the respondents as living in mobile-only households; landline-only households; landline and mobile telephone households; or having no landline or mobile in the household.

3.4.3 Sociodemographics

Demographic variables included age, sex, area of residence, country of birth, household size, household structure, educational attainment, marital status, gross annual household income, employment status, dwelling ownership or renting status (2013 only) and area-level socioeconomic status. The

Socioeconomic Indexes for Areas (SEIFA) Index of Relative Socioeconomic Disadvantage (IRSD) is a composite score of relative disadvantage developed by the ABS[151] for particular geographical areas, such as postcodes. It is based on selected 2011 Census sociodemographic variables. The SEIFA IRSD scores were grouped into quintiles for analysis where the highest quintile comprised postcodes with the highest SEIFA IRSD scores (most advantaged areas).

3.4.4 Comorbid conditions and health behaviours

Chronic conditions included self-reported medically confirmed diabetes (2010, 2011 and 2013 only), current asthma (2010 and 2011 only), arthritis and a current mental health condition. Self-reported health risk factor data included smoking status and obesity as determined by body mass index (BMI) which was derived from self-reported weight and height and recoded into four categories (underweight, normal weight, overweight and obese) [152].

3.4.5 Statistical analyses

Data analysis was conducted using Stata Version 12.0. All estimates and analyses were conducted using *svy* commands in Stata to incorporate the sampling design. Univariable analyses using chi-square tests compared the proportion of mobile-only households across sociodemographic variables for 2010, 2011, 2012 and 2013. Households that had no telecommunications, refused or where the status could not be determined were excluded from the analyses (n=39). The univariable analyses were limited to data from 2010, since data has been previously published for earlier years[107]. Additional univariable analyses using chi-square tests were undertaken to describe the proportion of households with a landline telephone connected; the proportion of households with mobile telephones; and the proportion of households with a directory-listed telephone number (EWP). These results can be found in supplementary tables.

To explore the possibility of coverage bias of telephone surveys, two hypothetical telephone sampling frames (subsamples) were created from HOS: 1) RDD landline, that is, households that had a landline connection (mobile-only households excluded); and 2) directory-listed numbers, that is, households with either a landline or mobile telephone number listed in the White Pages. Prevalence estimates of health conditions and behavioural risk factors were presented for the overall population, and the two hypothetical telephone samples. The hypothetical telephone samples were subsamples of the total sample (landline RDD sample is 72-78% of the total sample and directory-listed landline sample is 50-60% of the total sample) which means that these subsamples would have a different demographic profile to each other and the overall sample. Therefore the data for the hypothetical telephone samples were re-weighted to produce health estimates that are reflective of the South Australian population. Re-weighting is calculated by incorporating the original relative sample weights, and by age, sex and area of residence to the most recent Census or Estimated Residential Population for South Australia.

To determine the amount of bias of the prevalence estimates derived from the two hypothetical sampling frames, the relative coverage bias (RCB) was calculated by the following formula: $\frac{N_{nc}}{N} \cdot \frac{(p_c - p_{nc})}{P}$ [153]. This formula incorporates the proportion of the population that is not included in the hypothetical samples (N_{nc}/N), that is, 1) mobile-only households, and 2) households that do not have either a mobile or landline telephone number listed in the telephone directory (N_{nc} denotes the number in the sample that is not covered in the total sample, N). It also includes the differences in prevalence estimate obtained from the hypothetical samples, p_c, and from the sample not in the hypothetical samples, p_{nc}, divided by the prevalence estimate for the total population, P.

3.5 Results

Figure 3.1 shows the household landline and mobile telephone status from 2006 to 2013. Mobile telephone ownership was consistently around 90% during the

last eight years, rising from 89.7% (95% CI 88.5-90.9) in 2006 to 96.3% (95% CI 95.5-97.0) in 2013 (7.4% increase). The proportion of households that are mobile-only has increased by 431% over the eight year period from 5.2% (95% CI 4.4-6.0) in 2006 to 27.6% (95% CI 24.7-30.7) in 2013. In contrast, the proportion of landline ownership (households with landline telephone only, and households with both landline and mobile telephones) has decreased by 24.1% from 94.4% (95% CI 93.2 - 95.) in 2006, 87.3% (95% CI 85.7-88.8) in 2009 to 71.7% (95% CI 68.6-74.6) in 2013. Descriptive statistics for the participants for 2010 to 2013 are provided in Supplementary Table 1.

Figure 3.1: Household landline and mobile telephone status, South Australia, 2006 to 2013
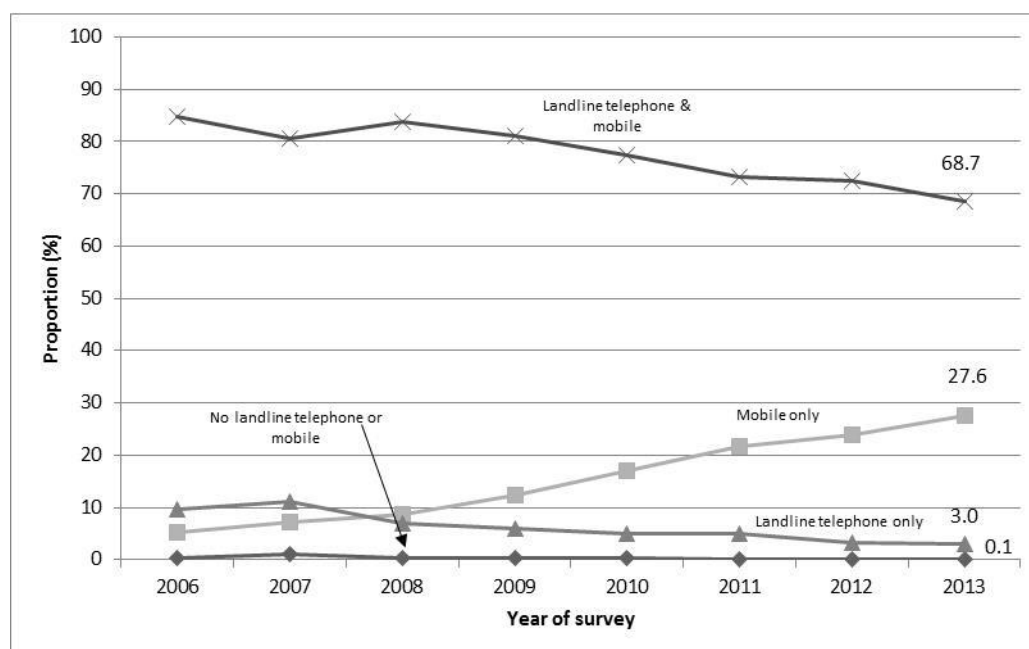
Table 3.1 shows the proportion of respondents living in mobile-only households by sociodemographic variables across the four years. Generally, respondents living in mobile-only household were more likely to be male, younger, of Aboriginal or Torres Strait Islander descent, born in Asia or countries other than Australia, UK, Ireland or Europe, never married, or separated or divorced, unemployed, fulltime employed, or home duties, renting privately or from the government, and to reside in the most disadvantaged areas. Largest percentage increases over the four years occurred amongst females (86.6%), people in the

older age groups (86.2%-159.4%), people living in rural areas of South Australia (80.4%), people born in the United Kingdom or Ireland (118.3%), people living in single parent households or shared-care parenting households (77.7%), or couples with no children (72.6%), widowed (131.4%), married or in a defacto relationship (75.2%), people with at least secondary schooling (81.0%), people living in households on low income levels (89.4%) or very high income levels (97.7%), and people who are retired (134.4%) or who are currently students (98.6%).

Supplementary Tables 2 and 3 show the proportion of respondents living in a household with a landline connection and the proportion of respondents living a household with at least one mobile telephone by sociodemographic variables for 2010 to 2013. The proportion of respondents living in households with directory-listed mobile or landline telephone (EWP) has been steadily decreasing from 73.8% (95% CI 72.2-75.4) in 2006, to 60.4% (95% CI 58.1-62.7) in 2010 and 49.6% (95% CI 46.2-53.0) in 2013. This proportion by sociodemographic characteristics for 2010 to 2013 is listed in Supplementary Table 4. In 2013, 4.6% (95% CI 3.8-5.5) of mobile numbers were listed in the telephone directory compared to 62.7% (95% CI 59.2-66.1) of landlines.

Table 3.1: Proportion of respondents living in mobile only households by sociodemographic variables, 15 years and over

	2010			2011			2012			2013		
	n	% (95% CI)	p value	n	% (95% CI)	p value	n	% (95% CI)	p value	n	% (95% CI)	p value
Sex												
Male	300	20.1 (17.5-22.9)	<0.001	339	22.8 (20.4-25.4)	0.158	391	26.2 (23.4-29.2)	0.005	409	28.8 (24.6-33.3)	0.288
Female	221	14.2 (12.3-16.3)		318	20.6 (18.1-23.3)		338	21.6 (19.5-23.9)		394	26.5 (23.6-29.6)	
Age (years)												
15 to 24	120	23.7 (18.9-29.3)	<0.001	145	28.7 (23.2-34.8)	<0.001	168	34.4 (28.4-41.0)	<0.001	171	36.9 (30.5-43.8)	<0.001
25 to 34	189	39.8 (34.7-45.1)		226	47.9 (42.4-53.4)		225	47.6 (41.8-53.6)		254	56.6 (49.2-63.7)	
35 to 44	96	18.8 (15.0-23.2)		149	29.1 (24.8-33.9)		146	28.9 (24.9-33.3)		168	35.0 (29.4-41.1)	
45 to 54	66	12.5 (9.7-15.9)		69	13.3 (10.2-17.0)		95	18.0 (14.5-22.2)		110	22.1 (17.5-27.6)	
55 to 64	31	7.0 (4.8-9.9)		36	8.0 (5.3-12.0)		69	14.9 (11.6-19.0)		61	13.7 (11.1-16.7)	
65 to 74	10	3.2 (1.9-5.3)		25	7.6 (5.4-10.6)		20	5.5 (3.8-7.7)		29	8.3 (6.1-11.2)	
75+	7	2.9 (1.5-5.5)		6	2.6 (1.3-5.1)		7	2.8 (1.4-5.4)		10	4.3 (2.5-7.2)	
Area of residence												
Metropolitan	369	16.4 (14.7-18.3)	0.315	461	20.6 (18.7-22.7)	0.122	503	22.2 (20.3-24.3)	0.005	549	25.4 (22.4-28.6)	0.016
Regional	151	18.9 (14.7-23.9)		196	24.6 (20.0-29.9)		226	28.5 (24.6-32.7)		254	34.1 (27.7-41.0)	
Number of people in household												
1	95	23.6 (20.6-26.8)	0.001	125	29.7 (26.4-33.3)	0.001	117	28.6 (23.4-34.4)	0.064	135	36.0 (31.2-41.0)	<0.001
2	267	16.7 (14.5-19.2)		352	22.5 (20.4-24.8)		397	24.9 (22.6-27.3)		433	28.6 (25.3-32.2)	
3	110	19.0 (15.2-23.3)		84	16.7 (12.7-21.7)		110	20.3 (16.3-25.1)		140	27.2 (21.6-33.6)	
4 or more	47	10.2 (6.6-15.6)		96	17.5 (12.8-23.4)		106	20.7 (15.9-26.5)		95	18.8 (14.9-23.4)	
Country of birth												
Australia	396	17.4 (15.5-19.5)	<0.001	488	22.0 (19.7-24.4)	<0.001	537	23.7 (21.6-26.0)	<0.001	595	27.9 (24.8-31.1)	0.002
UK or Ireland	25	9.3 (6.2-13.7)		39	13.7 (10.2-18.3)		61	17.9 (14.3-22.3)		60	20.3 (14.3-28.0)	
Europe	13	8.9 (5.3-14.6)		17	10.6 (6.6-16.7)		9	7.4 (3.9-13.8)		21	14.5 (10.8-19.1)	
Asia	47	29.8 (21.3-39.9)		78	32.9 (25.8-40.7)		81	41.0 (31.7-50.9)		74	35.8 (24.2-49.4)	
Other	39	19.9 (13.4-28.5)		34	26.4 (18.2-36.7)		41	31.7 (22.7-42.3)		53	42.4 (30.2-55.6)	
Aboriginal / Torres Strait Islander												
No	502	16.8 (15.0-18.7)	0.029	627	21.1 (19.2-23.1)	<0.001	686	23.1 (21.3-25.0)	<0.001	764	27.1 (24.3-30.0)	<0.001
Yes	18	35.2 (21.9-51.2)		29	53.2 (38.6-67.3)		39	51.5 (36.1-66.5)		36	53.9 (38.4-68.8)	

Table 3.1: Proportion of respondents living in mobile only households by sociodemographic variables, 15 years and over (cont.)

	2010			2011			2012			2013		
	n	% (95% CI)	p value	n	% (95% CI)	p value	n	% (95% CI)	p value	n	% (95% CI)	p value
Household structure												
Couple family children	135	12.6 (10.3-15.5)	<0.001	209	18.1 (15.4-21.2)	<0.001	232	21.2 (18.1-24.6)	<0.001	227	21.6 (18.0-25.6)	<0.001
One parent family, other	79	22.9 (18.2-28.3)		92	31.2 (25.4-37.7)		88	29.7 (24.7-35.1)		136	40.7 (35.0-46.7)	
Lone adult person	77	21.5 (18.3-25.1)		99	26.8 (23.3-30.7)		95	26.5 (21.7-31.9)		99	31.2 (26.6-36.3)	
Couple with no children	89	11.3 (9.0-14.1)		126	15.7 (13.2-18.6)		145	16.9 (14.3-19.9)		138	19.5 (16.7-22.6)	
Other	139	28.8 (23.7-34.5)		131	31.6 (26.1-37.6)		169	37.7 (31.5-44.4)		203	40.7 (34.5-47.2)	
Marital status												
Married/defacto	253	13.3 (11.5-15.3)	<0.001	335	17.9 (15.8-20.2)	<0.001	390	20.5 (18.2-22.9)	<0.001	417	23.3 (20.1-26.8)	<0.001
Separated/Divorced	46	21.4 (17.2-26.3)		75	30.5 (25.5-36.0)		88	33.6 (28.4-39.2)		91	34.4 (30.0-39.1)	
Widowed	9	5.1 (2.9-8.7)		12	7.6 (4.8-12.0)		14	8.1 (5.3-12.1)		16	11.7 (8.3-16.4)	
Never married	207	28.1 (24.1-32.5)		233	31.0 (26.8-35.7)		237	33.4 (28.9-38.3)		279	38.9 (33.9-44.1)	
Educational attainment												
Secondary schooling	212	15.3 (13.0-17.9)	0.128	268	21.5 (18.4-25.0)	0.819	292	23.3 (20.3-26.7)	0.702	329	27.7 (23.3-32.6)	0.745
Trade, certificate, diploma	192	18.7 (16.2-21.5)		246	21.2 (18.7-23.8)		272	24.3 (21.6-27.3)		293	27.6 (24.2-31.2)	
Bachelor degree or higher	115	18.3 (15.3-21.8)		141	22.9 (19.4-26.8)		165	24.2 (20.7-28.1)		181	27.7 (23.4-32.5)	
Gross annual household income												
Up to $20,000	45	16.0 (11.4-22.0)	0.073	47	17.3 (13.3-22.2)	0.042	58	24.4 (19.7-29.7)	0.25	53	30.3 (23.9-37.4)	0.005
$20,001 - $40,000	71	17.3 (13.7-21.5)		80	20.0 (16.0-24.7)		87	25.2 (20.7-30.4)		80	21.6 (16.6-27.6)	
$40,001 - $80,000	114	18.8 (15.4-22.7)		157	26.5 (22.8-30.7)		161	27.6 (23.8-31.8)		189	33.6 (28.9-38.5)	
$80,001 - $120,000	106	21.0 (17.2-25.5)		117	24.3 (20.1-29.1)		99	24.0 (19.6-29.0)		126	28.8 (23.9-34.3)	
$120,001 or more	57	13.1 (9.8-17.1)		86	19.1 (15.1-23.8)		115	21.7 (17.8-26.1)		151	25.9 (21.6-30.7)	
Not stated	128	15.8 (12.9-19.1)		169	20.3 (16.2-25.2)		210	22.1 (18.7-25.8)		203	26.1 (22.2-30.5)	
Employment status												
Fulltime employed	248	21.9 (19.1-25.1)	<0.001	315	26.9 (24.0-30.1)	<0.001	309	27.7 (24.7-31.0)	<0.001	371	36.2 (30.9-41.9)	<0.001
Parttime employed	108	18.4 (14.6-22.9)		128	22.0 (18.2-26.2)		135	24.5 (20.5-28.9)		157	26.5 (22.2-31.3)	
Home Duties	46	22.8 (17.5-29.3)		55	32.7 (25.4-40.9)		58	27.6 (21.8-34.3)		55	34.4 (27.1-42.6)	
Unemployed	23	35.8 (23.7-50.2)		32	35.2 (24.1-48.1)		51	57.7 (45.4-69.2)		40	42.0 (28.4-56.8)	
Retired	20	3.2 (2.1-4.9)		35	5.7 (4.1-7.9)		36	5.9 (4.4-7.7)		44	7.5 (5.5-10.2)	
Student	43	14.7 (10.2-20.7)		51	21.1 (14.3-29.9)		98	29.7 (23.0-37.3)		81	29.2 (23.3-36.0)	

Table 3.1: Proportion of respondents living in mobile only households by sociodemographic variables, 15 years and over (cont.)

	2010			2011			2012			2013		
	n	% (95% CI)	p value	n	% (95% CI)	p value	n	% (95% CI)	p value	n	% (95% CI)	p value
Other/not working due to health	32	20.0 (13.0-29.5)		38	23.4 (18.1-29.7)		41	28.8 (21.6-37.2)		53	32.6 (25.1-41.2)	
SEIFA IRSD quintile												
Lowest (most disadvantaged)	160	22.3 (18.1-27.1)	0.003	197	27.3 (23.4-31.5)	<0.001	227	30.3 (26.6-34.3)	<0.001	229	34.6 (28.1-41.7)	0.004
Low	86	17.8 (14.9-21.1)		179	29.3 (24.5-34.6)		137	26.8 (22.2-32.0)		186	31.0 (25.8-36.8)	
Middle	106	17.0 (13.5-21.3)		110	20.6 (16.8-25.0)		139	25.2 (21.2-29.6)		142	28.0 (21.8-35.1)	
High	84	15.1 (11.8-19.1)		81	15.7 (12.7-19.3)		110	19.8 (16.2-24.0)		120	22.2 (16.8-28.7)	
Highest (least disadvantaged)	84	12.6 (9.8-16.1)		91	13.9 (11.2-17.1)		116	16.9 (13.8-20.4)		125	21.0 (17.5-25.0)	
Dwelling status												
Owned or being purchased										396	18.3 (16.1-20.7)	<0.001
Rent from state government (public housing)										61	43.5 (34.5-52.9)	
Rent privately										330	58.6 (52.8-64.3)	
Other										9	33.4 (15.7-57.6)	
Overall	520	17.1 (15.3-19.0)		657	21.7 (19.7-23.8)		729	23.9 (22.0-25.9)		803	27.6 (24.7-30.7)	

Table 3.2: Prevalence of health conditions and risk factors for all households, and for landline Random Digit Dialling (RDD) and Directory-listed (EWP) telephone samples, 15 years and over

		2010			2011			2012			2013		
		n	% (95% CI)	RCB	n	% (95% CI)	RCB	n	% (95% CI)	RCB	n	% (95% CI)	RCB
Health conditions													
Diabetes	All households	229	7.5 (6.6-8.5)		246	8.1 (7.1-9.2)					247	8.5 (7.6-9.5)	
	Landline (RDD) sample	181	7.2 (6.2-8.3)	-0.009	195	8.3 (7.1-9.6)	0.003				173	8.3 (7.4-9.4)	-0.033
	Directory-listed sample	133	7.1 (6.0-8.5)	-0.021	148	8.6 (7.1-10.3)	0.030				117	7.9 (6.7-9.4)	-0.077
Current asthma	All households	416	13.6 (12.2-15.3)		384	12.7 (11.4-14.0)							
	Landline (RDD) sample	335	13.3 (11.7-15.2)	-0.015	297	12.6 (11.1-14.2)	-0.002						
	Directory-listed sample	246	13.1 (11.3-15.2)	-0.061	220	12.8 (10.9-15.0)	-0.014						
Arthritis	All households	653	21.4 (19.9-23.1)		727	24.0 (22.3-25.7)		656	21.5 (19.7-23.3)		640	22.0 (20.3-23.8)	
	Landline (RDD) sample	529	21.1 (19.5-22.8)	-0.025	554	23.5 (21.6-25.4)	-0.031	495	21.2 (19.3-23.2)	0.009	464	22.3 (20.4-24.4)	0.019
	Directory-listed sample	387	20.7 (18.9-22.6)	-0.083	407	23.7 (21.4-26.1)	-0.018	346	20.7 (18.5-23.2)	-0.046	324	22.0 (19.7-24.4)	-0.016
Mental health condition	All households	330	10.8 (9.6-12.2)		359	11.8 (10.7-13.1)		297	9.7 (8.7-10.8)		384	13.2 (11.8-14.7)	
	Landline (RDD) sample	250	10.0 (8.6-11.5)	-0.100	275	11.6 (10.3-13.1)	-0.046	222	9.5 (8.2-10.9)	-0.025	256	12.3 (10.7-14.1)	-0.091
	Directory-listed sample	167	8.9 (7.4-10.7)	-0.242	221	12.9 (11.0-15.0)	0.056	150	9.0 (7.6-10.6)	-0.102	172	11.6 (9.4-14.3)	-0.141
Health - related risk factors													
Current smoker	All households	614	20.2 (18.3-22.1)		529	17.4 (15.8-19.2)		501	16.4 (14.8-18.2)		552	19.0 (16.6-21.6)	
	Landline (RDD) sample	429	17.1 (15.2-19.2)	-0.136	343	14.5 (12.8-16.5)	-0.191	304	13.0 (11.4-14.9)	-0.174	330	15.9 (13.6-18.6)	-0.138
	Directory-listed sample	316	16.9 (14.7-19.3)	-0.129	223	13.0 (10.9-15.4)	-0.313	210	12.6 (10.8-14.7)	-0.181	202	13.7 (11.6-16.1)	-0.244
Obese	All households	611	22.1 (20.4-24.0)		612	22.7 (20.9-24.6)		621	23.4 (21.5-25.4)		603	23.1 (20.7-25.8)	
	Landline (RDD) sample	511	22.6 (20.7-24.6)	0.036	491	23.3 (21.2-25.5)	0.013	474	23.5 (21.4-25.8)	-0.020	454	24.3 (21.8-27.0)	0.078
	Directory-listed sample	379	22.5 (20.3-25.0)	-0.002	359	23.8 (21.2-26.6)	0.059	329	22.7 (20.1-25.5)	-0.050	329	24.6 (21.6-27.9)	0.079

Note: RCB: relative coverage bias; Landline (RDD) sample: households that had a landline connection (mobile-only households excluded); Directory-listed sample: households with either a landline or mobile telephone number listed in the White Pages

The prevalence estimates of various health conditions and behavioural risk factors for all households, for people who live in households with a landline connection (hypothetical landline RDD sample) and for people who live in a household with a directory-listed landline or mobile telephone number (hypothetical directory-listed sample) are shown in Table 3.2. The RCB for the prevalence estimates derived from the two hypothetical samples are also in Table 3.2. There were small absolute differences in the prevalence estimates for current asthma, arthritis and obesity between the hypothetical telephone samples and the overall sample. The prevalence estimates for diabetes by the two hypothetical samples did not differ in 2010 and 2011, however, the prevalence estimate was slightly under-estimated (RCB value of -0.077) in 2013 for the directory-listed sample. Even though the prevalence estimates for arthritis were similar for both hypothetical samples, the prevalence estimate for arthritis in 2010 was under-estimated for the directory-listed sample (RCB value of -0.083) compared to the overall sample (prevalence of 20.7% vs. 21.4%). The prevalence of having a mental health condition showed mixed results for both hypothetical samples and over time: the prevalence of having a mental health condition was under-estimated for both samples with estimates from the directory-listed sample having larger RCB (ranging from -0.102 to -0.242) with the exception of 2011, which had the opposite result of over-estimating mental health conditions (RCB value of 0.056). Current smoking prevalence was lower for both hypothetical telephone samples with absolute differences ranging from 2.9 to 3.4 percentage points for RDD landline samples and 3.3 to 5.3 percentage points for directory-listed samples, and associated large RCB values: -0.136 to -0.191 for RDD landline samples and -0.129 to -0.313 for directory-listed samples.

3.6 Discussion

This paper presents estimates and trends of telephone coverage in Australia from 2006 to 2013. Continual assessment of methodological issues around conducting population health telephone surveys is essential due to the rapid technological changes in telecommunications and the different 'user culture'

associated in use of these new and old telecommunication technologies. Even though telephone (landline and mobile) coverage in South Australia is very high (97%), nearly a third of households are mobile-only (27.8%) and only half of the households (49.0%) have either a mobile or landline number listed in the White Pages telephone directory. Our results show that mobile-only respondents are different across a range of sociodemographic indicators, which is similar to international studies[62, 110, 146]. Using hypothetical sampling frames (RDD landline and EWP directory listing) that were weighted to the age and sex structure of the South Australian population produced contradictory results for health prevalence estimates when compared to all households in the face-to-face survey. Prevalence estimates of diabetes, current asthma, arthritis and obesity had very minor differences and biases, but the prevalence estimates for mental health condition and current smoking indicates biases using either RDD landline or EWP directory listing sampling frame. Even though our results show that mobile-only respondents are demographically different across a range of sociodemographic indicators, appropriately weighted data can produce reliable prevalence estimates for some health indicators, but not for others. These findings suggest landline-based sampling frames used in Australia are potentially biased for some health indicators, such as current smokers and having a mental health condition, particularly where conditions or risk factors are higher amongst those living in mobile-only households. Researchers using either RDD or directory-listing landline sampling frames need to be aware of their limitations and know of the potential biased estimates because of the groups that are excluded from the sampling frames.

This study is important because it quantifies the potential biases from the various landline-based telephone sampling frames used in Australia and the groups that are potentially excluded. Even though the data are limited to South Australia, the conclusions may be generalisable to the Australian population. This study is unique since the same questions have been asked annually for eight years and, using the face-to-face methodology in which all types of households are included (mobile-only, landline-only or both), it had the ability to examine, over time, the prevalence estimates of various health indicators by

telephone status. Very few studies like this are known to exist nationally[143] and internationally[62, 146] and even fewer examine the assessment on health indicators[146].

The trends and demographic differences found in this study are similar to national and international studies [17, 62, 143, 146, 154, 155] and support findings from our previous research[107]. Our estimate of mobile-only households in 2012 (23.9%) was higher than the estimate reported by the Australian Communication and Media Authority (19%)[143]; the proportion of households with a landline telephone in 2010 was 82.5% which was slightly higher than the 80.3% estimate from the 2010-11 Australian Health Survey (AHS); and our estimate of 68.7% of landline telephone numbers listed in the telephone directory was slightly lower than the 70.1% from the AHS 2010-11 survey[156]. Between 2006 and 2008 the trend of mobile-only households remained low, however since 2009, the trend has steadily increased, following international patterns[146]. Similarly for landline ownership, up to 2011 the proportion was over 80%, however, this has steadily decreased to 71.9% in 2013. These changes are mainly due to the increasing popularity of greater flexibility and affordability offered by mobile technology. People are using landlines less frequently because they are able to have a single device with multiple communication and media services, which is less expensive than having a landline connection [110].

In our previous study[107], nearly 10% of the population in 2008 lived in mobile-only households, and we showed that with appropriate weighting, the sampling methodology used for telephone surveys produced reliable health estimates with the exception of smoking prevalence in South Australia being under-estimated. In contrast, with more recent data and up-to-date analyses, this study has estimated that close to 30% of the Australian population now live in mobile-only households and these analyses have demonstrated the impact of the vast changes in the telecommunication over the eight year study period on the coverage of the sampling frames. Excluding a distinct subpopulation from the landline sampling frames, namely mobile-only households, resulted in

under- or over-estimation in some health estimates, although with appropriate weighting most health estimates (except smoking and mental health) were very similar to the overall population. Even though the results in the health estimates (absolute differences and RCB values) between the overall population and the two hypothetical landline sample groups showed no clear pattern over time, the results do highlight that for specific health indicators, such as current smokers and mental health, the direction of the bias was consistently under-estimated for both RDD and directory-listed landline hypothetical samples. The other conditions (diabetes, current asthma, arthritis and obesity) had little absolute differences in health estimates and an inconsistent pattern, but relatively low, RCB values over time, which may suggest that the differences could be due to the random nature of the sample or other sampling errors. Our findings for current smokers, asthma and obesity are similar to other USA studies [146] using similar methodology, and are consistent with studies using dual-frame telephone surveys for mental health[157], current smoking[116, 146, 158], asthma[158], and obesity[146]. This suggests that perhaps an alternative sampling, surveying or statistical methodological approach may need to be considered to include groups of the population to remove the coverage biases in landline-based sampling frames.

Many studies have explored various methods to include the mobile-only group into chronic disease and risk factor surveillance systems[142, 159]. The favoured method is an over-lapping dual-frame design which involves two independent samples: a sample of mobile telephones and a landline-based sample[103, 106, 116, 118]. These studies showed an improvement in the representativeness, in particular for men, the younger and middle age groups, and people who were never married. However, obtaining a sample of mobile telephone numbers does have drawbacks, including low response rates and two to four times the costs of landline-based samples[103]. More importantly, the mobile sample that is currently available and used in Australia is of randomly generated mobile telephone numbers with no geographical marker. From a South Australian perspective, only 8% of all mobile telephone numbers in Australia were estimated to be owned by South Australians[103, 106, 116, 118], which is almost the

same proportion of the state's population (7.4%). This means a much larger initial sample is required for screening, and with the additional problem of low response rate, the feasibility of including mobile numbers using these methods in a chronic disease and behavioural risk factor surveillance system in South Australia would be costly. Even though 98% of South Australians have a mobile telephone and it is perceived that people can be reached anytime, it does not mean that they are willing or able to use it to complete a survey. Receiving mobile telephone calls can happen at unpredictable moments when it is not suitable for the owner to respond, such as driving (safety issue), travelling overseas (which can incur a large cost to the researcher or participant), or during a meeting or in a restaurant (privacy issue); all have an impact on response rates[155].

Mixed-mode methods have also been suggested as a way to complement the traditional landline telephone survey by combining face-to-face, mail, and online surveys[73]. These alternative modes introduce other methodological issues and the design of each mode need to be taken into consideration. The questionnaire design for CATI surveys, for example, complicated skips patterns or data range checks, needs to be careful considered in other modes such as mail survey[160]. Face-to-face, mail and online survey can have the option of longer worded questions, explanations, and visual or prompt cards which is not recommended or possible with CATI surveys. Therefore, the wording of the questions in telephone surveys needs to be clear, concise and short[61]. Operational differences can have an impact on how the questions are answered. Telephone surveys are mainly interviewer administered whereas mail or online surveys are self-administered which can lead to different responses[73, 160]. In telephone surveys, the interviewer has control over who is the selected respondent within the household whereby in the mail or online surveys any member of the household determines who is the selected[142]. The level of privacy can vary by survey modes which is high with mail or online surveys compared to moderate level of privacy with telephone (others listening in, or answering sensitive questions)[161]. Mail surveys require a longer data collection period compared to the allocated time period for telephone surveys.

In an attempt to include respondents from mobile-only households, a study examined the possibly of using two modes, telephone and mail, with a single database that consisted of residential addresses. However, they found that the groups that were under-represented in telephone surveys were also under-represented in the mail surveys[159]. Another consideration for surveillance systems that used the telephone to collect data, is the challenge of how to incorporate alternative modes but still maintain the timeliness, flexibility, low non-response and low cost of the system[142]. Other methodological studies have used statistical approaches such as alternative weighting strategies, such as raked weights, which incorporate a wider range of sociodemographic variables, can improve the health estimates and are more in line with face-to-face surveys[15, 134, 140].

The study design used in this research is robust due to the large representative state-wide samples used and is unique in that the data were collected over eight years using the same or similar questions, and by one organisation, thus minimising interviewer biases. These data are also very recent and it is one of the few face-to-face studies conducted in Australia and worldwide that included questions on landline and mobile telephone status that also had questions on health status and behavioural risk factors [146] so the biases in health estimates can be assessed. However the results could be biased due to the moderately acceptable response rates (median = 59.3%) which is following the trends observed interstate and overseas. This study only analysed a few health-related variables and additional questions such as health service usage, quality-of-life or alcohol consumption would have provided a more comprehensive description of telephone sampling biases.

Telephone surveys have become a standard and accepted method of collecting health information in Australia and are widely used to monitor chronic disease and behavioural risk factors. Such surveillance systems provide evidence to inform interventions and service planning with the aim of reducing the impact of chronic diseases and their associated costs to the health system. Analyses like those presented here are important to demonstrate that the health

estimates obtained are not biased due to sampling methodology. This study has shown that the proportion of mobile-only households is increasing and this does not appear to have reached a plateau. This corresponds with the decrease in landline telephone coverage. Even with appropriately weighted data, using landline-based sampling frames in Australia are potentially biased for some health indicators. This implies that the landline sampling frames that are currently used in most Australian chronic disease and risk factor surveillance systems (RDD landline or directory-listed telephone numbers) are not sufficient on their own because of the exclusion of the mobile-only households. Other methodologies need to be considered for small states like South Australia that are timely, cost-effective and efficient.

3.7 Appendix 1: Supplementary Tables

Supplementary Table 1: Sample sociodemographic profile by survey year, 15 years and over

	2010		2011		2012		2013	
	n	% (95% CI)	n	% (95% CI)	n	% (95% CI)	n	% (95% CI)
Sex								
Male	1493	49.0 (46.8 - 51.2)	1486	49.0 (47.2 - 50.9)	1494	48.9 (46.8 - 50.9)	1422	48.9 (46.5 - 51.3)
Female	1553	51.0 (48.8 - 53.2)	1546	51.0 (49.1 - 52.8)	1561	51.1 (49.1 - 53.2)	1486	51.1 (48.7 - 53.5)
Age (years)								
15 to 24	507	16.7 (14.9 - 18.4)	505	16.7 (14.8 - 18.5)	487	15.9 (14.1 - 17.8)	464	15.9 (14.4 - 17.7)
25 to 34	475	15.6 (14.0 - 17.2)	473	15.6 (14.0 - 17.2)	472	15.4 (13.8 - 17.1)	449	15.4 (13.2 - 18.0)
35 to 44	513	16.9 (15.2 - 18.5)	511	16.9 (15.3 - 18.4)	505	16.5 (14.8 - 18.3)	480	16.5 (15.1 - 18.0)
45 to 54	525	17.2 (15.7 - 18.7)	523	17.2 (15.8 - 18.7)	525	17.2 (15.5 - 18.9)	499	17.2 (15.5 - 19.0)
55 to 64	452	14.8 (13.4 - 16.3)	450	14.8 (13.5 - 16.1)	466	15.2 (13.7 - 16.8)	443	15.2 (13.9 - 16.7)
65 to 74	318	10.4 (9.2 - 11.6)	327	10.8 (9.6 - 12.0)	362	11.8 (10.6 - 13.1)	346	11.9 (10.8 - 13.1)
75+	255	8.4 (7.4 - 9.4)	243	8.0 (7.1 - 9.0)	239	7.8 (6.7 - 9.0)	226	7.8 (6.5 - 9.2)
Area of residence								
Metropolitan	2245	73.7 (68.8 - 78.6)	2235	73.7 (68.7 - 78.7)	2235	73.2 (66.7 - 79.6)	2163	74.4 (65.1 - 81.9)
Regional	801	26.3 (21.4 - 31.2)	797	26.3 (21.3 - 31.3)	820	26.8 (20.4 - 33.3)	745	25.6 (18.1 - 34.9)
Country of birth								
Australia	2277	74.7 (72.7 - 76.8)	2221	73.3 (71.3 - 75.2)	2267	74.2 (72.3 - 76.1)	2138	73.5 (70.5 - 76.3)
UK or Ireland	267	8.8 (7.6 - 9.9)	285	9.4 (8.2 - 10.6)	341	11.2 (9.9 - 12.5)	293	10.1 (7.8 - 13.0)
Europe	149	4.9 (4.1 - 5.7)	157	5.2 (4.4 - 6.0)	122	4.0 (3.3 - 4.7)	147	5.1 (3.9 - 6.6)
Asia	157	5.2 (4.0 - 6.3)	239	7.9 (6.5 - 9.3)	197	6.5 (5.1 - 7.8)	206	7.1 (5.0 - 10.0)
Other	196	6.5 (5.3 - 7.6)	130	4.3 (3.4 - 5.2)	128	4.2 (3.3 - 5.0)	124	4.3 (3.4 - 5.3)
Household structure								
Couple family children	1068	35.1 (32.8 - 37.4)	1152	38.0 (35.8 - 40.2)	1095	35.9 (33.7 - 38.0)	1049	36.1 (33.4 - 38.9)
One parent family, other	348	11.4 (10.0 - 12.8)	295	9.7 (8.4 - 11.0)	298	9.8 (8.2 - 11.3)	334	11.5 (9.7 - 13.5)
Lone adult person	359	11.8 (10.7 - 12.9)	368	12.1 (11.1 - 13.2)	358	11.7 (10.7 - 12.7)	317	10.9 (9.8 - 12.1)
Couple with no children	788	25.9 (23.5 - 28.3)	801	26.4 (24.6 - 28.2)	855	28.0 (26.0 - 30.0)	709	24.4 (21.9 - 27.1)
Other	484	15.9 (13.7 - 18.0)	416	13.7 (11.9 - 15.5)	448	14.7 (13.0 - 16.4)	499	17.2 (14.0 - 20.9)

Supplementary Table 1: Sample sociodemographic profile by survey year, 15 years and over (cont.)

	2010		2011		2012		2013	
	n	% (95% CI)	n	% (95% CI)	n	% (95% CI)	n	% (95% CI)
Marital status								
Married/defacto	1906	62.6 (60.4 - 64.7)	1871	61.7 (59.7 - 63.7)	1905	62.4 (60.3 - 64.4)	1791	61.6 (59.0 - 64.1)
Separated/Divorced	217	7.1 (6.3 - 8.0)	246	8.1 (7.2 - 9.0)	261	8.5 (7.6 - 9.5)	264	9.1 (7.9 - 10.4)
Widowed	180	5.9 (5.2 - 6.7)	161	5.3 (4.6 - 6.0)	176	5.8 (5.1 - 6.5)	133	4.6 (3.9 - 5.3)
Never married	736	24.2 (22 - 26.3)	751	24.8 (22.8 - 26.7)	710	23.2 (21.3 - 25.2)	718	24.7 (22.4 - 27.1)
Educational attainment								
Secondary schooling	1386	45.5 (43.1 - 47.9)	1247	41.1 (38.7 - 43.6)	1251	41.0 (38.1 - 43.8)	1187	40.8 (36.5 - 45.3)
Trade quals, Certificate,	1027	33.7 (31.7 - 35.7)	1162	38.3 (36.2 - 40.5)	1119	36.6 (34.5 - 38.7)	1061	36.5 (32.5 - 40.7)
Bachelor Degree	629	20.7 (18.4 - 22.9)	617	20.4 (18.5 - 22.3)	682	22.3 (19.9 - 24.7)	651	22.4 (18.1 - 27.4)
Gross annual household income								
Up to $20,000	280	9.2 (8.1 - 10.3)	274	9.0 (7.9 - 10.2)	239	7.8 (6.7 - 8.9)	176	6.0 (5.0 - 7.3)
$20,001 - $40,000	410	13.5 (12.1 - 14.8)	401	13.2 (11.8 - 14.7)	344	11.3 (10 - 12.5)	372	12.8 (11.1 - 14.7)
$40,001 - $80,000	607	19.9 (18.2 - 21.6)	590	19.5 (17.8 - 21.1)	582	19.1 (17.4 - 20.7)	562	19.3 (17.3 - 21.5)
$80,001 - $120,000	504	16.5 (14.5 - 18.6)	481	15.9 (13.9 - 17.8)	412	13.5 (11.9 - 15.0)	438	15.1 (13.5 - 16.7)
$120,001 or more	438	14.4 (12.7 - 16.1)	452	14.9 (13 - 16.8)	530	17.3 (15.3 - 19.4)	584	20.1 (16.8 - 23.8)
Not stated	808	26.5 (24.3 - 28.7)	834	27.5 (25.0 - 30.0)	948	31.0 (28.4 - 33.6)	776	26.7 (23.7 - 29.9)
Employment status								
Full - time employed	1131	37.1 (35.1 - 39.2)	1171	38.6 (36.6 - 40.6)	1115	36.5 (34.3 - 38.7)	1025	35.3 (32.6 - 38)
Part - time employed	586	19.2 (17.7 - 20.8)	582	19.2 (17.6 - 20.7)	553	18.1 (16.5 - 19.7)	591	20.3 (18.3 - 22.5)
Home Duties	203	6.7 (5.6 - 7.8)	168	5.5 (4.6 - 6.5)	211	6.9 (5.5 - 8.3)	161	5.5 (4.4 - 6.9)
Unemployed	65	2.1 (1.5 - 2.7)	90	3.0 (2.2 - 3.8)	89	2.9 (2.1 - 3.7)	96	3.3 (2.4 - 4.6)
Retired	608	20.0 (18.2 - 21.7)	610	20.1 (18.5 - 21.7)	614	20.1 (18.3 - 21.9)	593	20.4 (18.2 - 22.7)
Student	292	9.6 (8.1 - 11.1)	241	7.9 (6.5 - 9.4)	330	10.8 (9.1 - 12.5)	275	9.5 (8.2 - 10.9)
Other/Not working due to illness	161	5.3 (4.1 - 6.5)	164	5.4 (4.5 - 6.4)	144	4.7 (3.8 - 5.6)	163	5.6 (4.6 - 6.8)

Supplementary Table 1: Sample sociodemographic profile by survey year, 15 years and over (cont.)

	2010 n	2010 % (95% CI)	2011 n	2011 % (95% CI)	2012 n	2012 % (95% CI)	2013 n	2013 % (95% CI)
SEIFA IRSD quintile								
Lowest (most disadvantaged)	716	23.5 (16.9 - 30.1)	721	23.8 (17.0 - 30.5)	750	24.5 (17.7 - 31.4)	663	22.8 (14.8 - 33.5)
Low	485	15.9 (11.2 - 20.7)	609	20.1 (14.9 - 25.3)	513	16.8 (11.5 - 22.0)	600	20.6 (14.6 - 28.4)
Middle	622	20.4 (15.8 - 25.1)	532	17.5 (13.3 - 21.8)	551	18.0 (13.8 - 22.3)	508	17.5 (11.3 - 26.1)
High	558	18.3 (14.3 - 22.4)	513	16.9 (13.3 - 20.5)	555	18.2 (14.3 - 22.1)	543	18.7 (12.4 - 27.1)
Highest (least disadvantaged)	664	21.8 (17.7 - 25.9)	657	21.7 (17.4 - 25.9)	686	22.5 (18.1 - 26.8)	595	20.5 (12.7 - 31.4)
	3046	100.0	3032	100.0	3055	100.0	2908	100.0

Note: weighted sample

Supplementary Table 2: Proportion of respondents living in households with a landline connection (RDD) by sociodemographic variables, 15 years and over

	2010	2010 % (95% CI)	2010 p value	2011	2011 % (95% CI)	2011 p value	2012	2012 % (95% CI)	2012 p value	2013	2013 % (95% CI)	2013 p value
Sex												
Male	1177	78.8 (75.7-81.7)	<0.001	1144	77.0 (74.4-79.4)	0.167	1097	73.5 (70.5-76.3)	0.005	999	70.3 (65.8-74.4)	0.184
Female	1325	85.4 (82.9-87.5)		1224	79.2 (76.5-81.7)		1219	78.1 (75.7-80.2)		1086	73.0 (69.9-75.9)	
Age (years)												
15 to 24	381	75.2 (68.9-80.6)	<0.001	359	71.1 (65.0-76.6)	<0.001	316	64.8 (58.1-71.0)	<0.001	289	62.4 (55.4-68.9)	<0.001
25 to 34	279	58.8 (53.6-63.7)		247	52.1 (46.6-57.6)		246	52.2 (46.2-58.1)		189	42.0 (34.9-49.5)	
35 to 44	416	81.0 (76.5-84.8)		361	70.7 (65.9-75.0)		359	71.1 (66.7-75.1)		310	64.4 (58.5-70.0)	
45 to 54	456	86.8 (83.3-89.6)		452	86.4 (82.6-89.4)		427	81.3 (77.1-85.0)		385	77.1 (71.5-81.8)	
55 to 64	417	92.3 (88.9-94.7)		413	91.8 (87.9-94.5)		395	84.8 (80.7-88.2)		381	85.9 (82.8-88.6)	
65 to 74	307	96.7 (94.6-98.0)		302	92.3 (89.2-94.5)		342	94.5 (92.3-96.2)		316	91.4 (88.4-93.6)	
75+	246	96.4 (93.4-98.0)		235	96.9 (94.1-98.4)		231	96.9 (94.3-98.3)		215	95.3 (92.2-97.3)	

Supplementary Table 2: Proportion of respondents living in households with a landline connection (RDD) by sociodemographic variables, 15 years and over

	2010			2011			2012			2013		
		% (95% CI)	p value		% (95% CI)	p value		% (95% CI)	p value		% (95% CI)	p value
Area of residence												
Metropolitan	1872	83.4 (81.5-85.1)	0.133	1772	79.2 (77.2-81.2)	0.107	1754	77.6 (75.5-79.5)	0.004	1599	73.9 (70.6-77.0)	0.015
Regional	631	78.7 (71.8-84.3)		597	75.0 (69.8-79.6)		562	70.8 (66.4-74.9)		486	65.2 (58.4-71.4)	
Number of people in household												
1	301	74.3 (70.6-77.6)	<0.001	293	69.7 (66.0-73.1)	<0.001	286	70.1 (64.0-75.6)	0.046	233	62.0 (57.0-66.7)	<0.001
2	1324	82.9 (80.1-85.4)		1207	77.3 (75.0-79.4)		1198	75.1 (72.6-77.3)		1075	71.0 (67.5-74.3)	
3	464	79.6 (75.0-83.6)		418	83.0 (78.1-87.1)		429	79.3 (74.3-83.6)		370	71.9 (65.5-77.5)	
4 or more	414	89.8 (84.4-93.4)		451	82.5 (76.6-87.2)		403	79.0 (73.3-83.8)		407	80.8 (76.0-84.8)	
Country of birth												
Australia	1858	81.6 (78.9-84.0)	<0.001	1728	77.8 (75.4-80.0)	<0.001	1723	76 (73.6-78.2)	<0.001	1527	71.4 (68.2-74.5)	0.001
UK or Ireland	242	90.5 (86.0-93.7)		245	85.8 (81.2-89.4)		279	81.8 (77.5-85.5)		232	79.1 (71.3-85.2)	
Europe	135	91.1 (85.4-94.7)		141	89.4 (83.3-93.4)		113	92.6 (86.2-96.1)		125	85.3 (80.8-88.9)	
Asia	110	70.2 (60.1-78.7)		160	67.1 (59.3-74.2)		115	58.3 (48.5-67.5)		131	63.6 (50.1-75.3)	
Other	157	80.1 (71.5-86.6)		95	73.6 (63.3-81.8)		87	68.0 (57.4-77.0)		70	56.0 (43.0-68.2)	
Aboriginal / Torres Strait Islander												
No	2472	82.7 (80.4-84.7)	<0.001	2342	78.8 (76.8-80.6)	<0.001	2273	76.6 (74.6-78.5)	<0.001	2040	72.3 (69.3-75.1)	<0.001
Yes	26	51.9 (33.5-69.8)		24	43.8 (30.0-58.6)		36	46.9 (32.2-62.2)		30	44.7 (29.7-60.8)	
Household structure												
Couple family children	928	86.9 (83.7-89.5)	<0.001	942	81.8 (78.7-84.5)	<0.001	862	78.7 (75.2-81.8)	<0.001	818	77.9 (73.8-81.6)	<0.001
One parent family, other	266	76.6 (71.0-81.4)		203	68.8 (62.3-74.6)		207	69.6 (63.9-74.7)		196	58.7 (52.5-64.6)	
Lone adult person	275	76.6 (72.8-79.9)		267	72.5 (68.6-76.1)		259	72.3 (66.5-77.3)		211	66.7 (61.7-71.3)	
Couple with no children	698	88.7 (85.9-91.0)		673	84.1 (81.2-86.6)		709	83.0 (79.9-85.6)		569	80.2 (77.2-83.0)	
Other	335	69.3 (63.3-74.6)		284	68.2 (62.1-73.7)		279	62.2 (55.5-68.4)		291	58.3 (52.2-64.1)	

Supplementary Table 2: Proportion of respondents living in households with a landline connection (RDD) by sociodemographic variables, 15 years and over (cont.)

	2010			2011			2012			2013		
		% (95% CI)	p value		% (95% CI)	p value		% (95% CI)	p value		% (95% CI)	p value
Marital status												
Married/defacto	1651	86.6 (84.5-88.4)	<0.001	1532	81.9 (79.6-84.0)	<0.001	1513	79.4 (77.0-81.6)	<0.001	1369	76.4 (72.9-79.6)	<0.001
Separated/Divorced	166	76.5 (71.2-81.0)		170	69.2 (63.7-74.2)		172	65.7 (59.9-71.1)		170	64.5 (59.9-68.9)	
Widowed	169	93.9 (89.4-96.6)		148	92.1 (87.7-95.0)		162	91.7 (87.7-94.4)		116	87.3 (82.8-90.8)	
Never married	515	70.0 (64.7-74.7)		517	68.8 (64.1-73.1)		468	65.9 (60.8-70.6)		429	59.8 (54.6-64.7)	
Educational attainment												
Secondary schooling	1153	83.2 (79.8-86.2)	0.148	975	78.2 (74.8-81.3)	0.863	955	76.3 (72.8-79.5)	0.86	849	71.5 (66.7-75.9)	0.869
Trade, certificate, diploma	834	81.2 (78.3-83.7)		914	78.6 (76.0-81.1)		844	75.4 (72.5-78.1)		761	71.8 (68.0-75.2)	
Bachelor degree or higher	514	81.7 (78.2-84.7)		476	77.1 (73.2-80.6)		515	75.5 (71.6-79.0)		469	72.0 (67.1-76.4)	
Gross annual household income												
Up to $20,000	227	80.9 (74.1-86.3)	0.134	223	81.4 (76.2-85.8)	0.065	177	74.1 (68.4-79.0)	0.293	120	68.3 (61.0-74.8)	0.006
$20,001 - $40,000	336	82.0 (77.6-85.7)		321	80.0 (75.3-84.0)		257	74.8 (69.6-79.3)		290	77.8 (71.8-82.8)	
$40,001 - $80,000	491	80.9 (76.8-84.4)		433	73.5 (69.3-77.2)		422	72.4 (68.2-76.2)		369	65.6 (60.8-70.2)	
$80,001 - $120,000	398	79.0 (74.5-82.8)		363	75.5 (70.7-79.7)		312	75.7 (70.7-80.1)		310	70.9 (65.3-75.9)	
$120,001 or more	380	86.9 (82.9-90.2)		366	80.9 (76.2-84.9)		415	78.3 (73.9-82.2)		431	73.8 (68.7-78.4)	
Not stated	671	83.1 (78.8-86.6)		663	79.5 (74.6-83.6)		734	77.4 (73.5-80.9)		565	72.8 (68.4-76.8)	
Employment status												
Fulltime employed	880	77.8 (74.6-80.6)	<0.001	856	73.1 (69.9-76.0)	<0.001	803	72.0 (68.8-75.0)	<0.001	646	63.0 (57.3-68.4)	<0.001
Parttime employed	478	81.6 (77.1-85.4)		451	77.5 (73.3-81.3)		418	75.5 (71.1-79.5)		432	73.1 (68.2-77.5)	
Home Duties	156	76.7 (70.1-82.2)		113	67.3 (59.1-74.6)		152	72.4 (65.7-78.2)		105	65.2 (57.2-72.4)	
Unemployed	41	63.1 (48.4-75.8)		58	64.0 (51.2-75.1)		37	41.5 (30.1-54.0)		55	57.4 (42.3-71.2)	
Retired	585	96.3 (94.3-97.6)		574	94.0 (91.8-95.7)		576	93.9 (92.1-95.4)		545	92.0 (89.2-94.1)	
Student	245	83.7 (76.0-89.3)		190	78.9 (70.1-85.7)		230	69.8 (62.1-76.5)		192	69.8 (62.5-76.3)	
Other/Not working due to health	118	73.7 (65.4-80.5)		125	76.0 (70.0-81.2)		100	69.4 (61.0-76.7)		108	66.2 (57.4-74.1)	

Supplementary Table 2: Proportion of respondents living in households with a landline connection (RDD) by sociodemographic variables, 15 years and over (cont.)

	2010			2011			2012			2013		
		% (95% CI)	p value		% (95% CI)	p value		% (95% CI)	p value		% (95% CI)	p value
SEIFA IRSD quintile												
Lowest (most disadvantaged)	540	75.4 (69.0-80.9)	0.001	523	72.5 (68.3-76.4)	<0.001	518	69.0 (64.9-72.9)	<0.001	425	64.1 (57.6-70.1)	0.002
Low	396	81.6 (78.3-84.5)		429	70.4 (65.1-75.2)		375	73.1 (68.0-77.7)		409	68.2 (62.3-73.5)	
Middle	512	82.4 (77.7-86.2)		421	79.1 (74.8-82.9)		410	74.5 (70.1-78.4)		363	71.5 (64.0-78.1)	
High	474	84.9 (80.9-88.2)		432	84.2 (80.5-87.2)		444	80.0 (75.9-83.6)		420	77.4 (70.7-82.9)	
Highest (least disadvantaged)	580	87.4 (83.9-90.2)		564	85.9 (82.7-88.6)		569	82.9 (79.4-85.9)		468	78.6 (74.6-82.2)	
Dwelling status												
Owned or being purchased										1758	81.3 (78.9-83.5)	<0.001
Rent from state government (public housing)										76	54.1 (44.6-63.3)	
Rent privately										227	40.3 (34.6-46.3)	
Other										16	63.3 (37.1-83.4)	
Overall	2503	82.2 (79.9-84.2)		2369	78.1 (76.0-80.1)		2316	75.8 (73.7-77.8)		2085	71.7 (68.5-74.6)	

Supplementary Table 3: Proportion of respondents living in households with at least one mobile telephone by sociodemographic variables, 15 years and over

	2010			2011			2012			2013		
		% (95% CI)	p value		% (95% CI)	p value		% (95% CI)	p value		% (95% CI)	p value
Sex												
Male	1420	95.1 (93.6-96.2)	0.050	1440	96.9 (96.0-97.5)	<0.001	1450	97.1 (96.2-97.8)	0.007	1381	97.1 (96.2-97.9)	0.008
Female	1454	93.6 (92.3-94.7)		1435	92.9 (91.6-93.9)		1494	95.7 (94.5-96.6)		1420	95.5 (94.4-96.5)	
Age (years)												
15 to 24	502	98.9 (95.8-99.7)	<0.001	502	99.5 (97.8-99.9)	<0.001	483	99.2 (96.7-99.8)	<0.001	460	99.2 (97.0-99.8)	<0.001
25 to 34	464	97.5 (92.6-99.2)		473	99.9 (99.4-100.0)		471	99.8 (99.4-100.0)		443	98.6 (96.6-99.4)	
35 to 44	512	99.7 (98.8-99.9)		508	99.5 (98.6-99.8)		503	99.6 (98.2-99.9)		478	99.4 (98.3-99.8)	
45 to 54	517	98.5 (97.1-99.3)		513	98.2 (96.9-98.9)		516	98.3 (97.0-99.1)		493	98.7 (97.3-99.4)	
55 to 64	435	96.2 (94.2-97.6)		430	95.5 (93.4-97.0)		454	97.6 (96.1-98.5)		434	98.0 (96.4-98.9)	
65 to 74	288	90.5 (87.2-93.0)		289	88.4 (85.1-91.2)		344	95.2 (92.9-96.8)		330	95.3 (93.6-96.6)	
75+	156	61.3 (55.9-66.4)		159	65.5 (60.3-70.3)		172	71.9 (67.1-76.3)		163	72.3 (66.9-77.2)	
Area of residence												
Metropolitan	2126	94.7 (93.8-95.5)	0.304	2134	95.4 (94.5-96.2)	0.003	2188	96.7 (96.0-97.3)	0.127	2088	96.5 (95.5-97.3)	0.270
Regional	747	93.2 (89.5-95.7)		741	93.1 (91.6-94.4)		756	95.3 (92.8-97.0)		713	95.7 (94.5-96.7)	
Number of people in household												
1	313	77.3 (74.1-80.2)	<0.001	334	79.5 (76.8-82.0)	<0.001	342	84.0 (81.3-86.4)	<0.001	320	85.3 (81.8-88.2)	<0.001
2	1527	95.6 (94.2-96.7)		1497	95.9 (94.8-96.8)		1560	97.7 (96.9-98.3)		1473	97.3 (96.4-97.9)	
3	571	98.1 (96.0-99.1)		498	98.9 (97.0-99.6)		533	98.5 (96.7-99.3)		508	98.8 (96.9-99.6)	
4 or more	462	100.0		545	99.7 (98.0-100.0)		509	99.7 (98.0-100.0)		500	99.1 (96.6-99.8)	
Country of birth												
Australia	2164	95.0 (93.7-96.1)	<0.001	2126	95.7 (94.9-96.4)	<0.001	2195	96.8 (95.9-97.5)	<0.001	2068	96.7 (96.0-97.4)	<0.001
UK or Ireland	240	89.9 (86.5-92.6)		258	90.4 (86.9-93.0)		325	95.2 (93.1-96.6)		281	95.7 (93.2-97.4)	
Europe	128	86.0 (80.6-90.1)		134	85.3 (79.3-89.8)		108	89.1 (82.8-93.3)		130	88.4 (81.5-93.0)	
Asia	156	99.1 (96.3-99.8)		236	98.9 (96.6-99.6)		193	97.9 (94.5-99.2)		204	99.3 (96.3-99.9)	
Other	186	94.7 (91.2-96.9)		121	93.6 (88.3-96.5)		123	96.6 (91.9-98.6)		118	95.0 (86.7-98.2)	

Supplementary Table 3: Proportion of respondents living in households with at least one mobile telephone by sociodemographic variables, 15 years and over (cont.)

	2010			2011			2012			2013		
		% (95% CI)	p value		% (95% CI)	p value		% (95% CI)	p value		% (95% CI)	p value
Aboriginal / Torres Strait Islander												
No	2826	94.5 (93.4-95.4)	0.078	2819	94.8 (94.0-95.5)	0.778	2860	96.4 (95.6-97.1)	0.947	2719	96.4 (95.5-97.0)	0.140
Yes	43	84.9 (71.2-92.8)		52	96.3 (87.9-98.9)		74	95.9 (92.0-98.0)		65	97.2 (91.8-99.1)	
Household structure												
Couple family children	1063	99.6 (98.3-99.9)	<0.001	1146	99.4 (98.6-99.8)	<0.001	1090	99.5 (98.7-99.8)	<0.001	1044	99.5 (98.6-99.9)	<0.001
One parent family, other	344	98.8 (97.1-99.5)		293	99.3 (97.9-99.8)		295	99.1 (96.4-99.8)		332	99.4 (98.3-99.8)	
Lone adult person	267	74.3 (70.4-77.8)		282	76.6 (73.4-79.4)		294	82.2 (79.2-84.8)		259	81.7 (77.9-85.0)	
Couple with no children	743	94.3 (92.5-95.7)		751	93.8 (92.0-95.2)		824	96.3 (94.8-97.4)		680	95.8 (94.1-97.0)	
Other	457	94.5 (91.9-96.3)		403	97.0 (94.9-98.3)		441	98.3 (96.5-99.2)		486	97.5 (96.0-98.5)	
Marital status												
Married/defacto	1847	96.9 (96.0-97.6)	<0.001	1809	96.7 (95.8-97.4)	<0.001	1866	97.9 (97.2-98.5)	<0.001	1752	97.8 (97.1-98.4)	<0.001
Separated/Divorced	199	91.6 (88.3-94.1)		220	89.5 (86.5-91.9)		248	95.1 (92.9-96.6)		249	94.3 (91.5-96.2)	
Widowed	113	62.4 (56.5-68.0)		110	68.2 (62.7-73.3)		132	75.0 (70.0-79.4)		97	73.1 (67.5-78.2)	
Never married	709	96.3 (92.9-98.1)		732	97.5 (96.2-98.4)		695	98.0 (96.4-98.8)		703	97.9 (96.4-98.8)	
Educational attainment												
Secondary schooling	1256	90.7 (88.9-92.1)	<0.001	1140	91.5 (89.9-92.8)	<0.001	1175	93.9 (92.3-95.2)	<0.001	1113	93.8 (92.2-95.1)	<0.001
Trade, certificate, diploma	990	96.4 (95.0-97.4)		1123	96.6 (95.6-97.3)		1095	97.8 (97.0-98.5)		1037	97.8 (96.8-98.5)	
Bachelor degree or higher	625	99.4 (98.6-99.7)		607	98.2 (97.1-98.9)		672	98.6 (97.5-99.2)		644	98.9 (97.5-99.5)	

Supplementary Table 3: Proportion of respondents living in households with at least one mobile telephone by sociodemographic variables, 15 years and over (cont.)

	2010			2011			2012			2013		
		% (95% CI)	p value		% (95% CI)	p value		% (95% CI)	p value		% (95% CI)	p value
Gross annual household income												
Up to $20,000	194	69.3 (64.3-73.9)	<0.001	211	77.1 (73.1-80.7)	<0.001	200	83.7 (79.6-87.1)	<0.001	137	78.3 (73.7-82.3)	<0.001
$20,001 - $40,000	378	92.3 (89.3-94.5)		361	90.2 (87.4-92.4)		327	95.1 (92.8-96.7)		345	92.6 (89.6-94.7)	
$40,001 - $80,000	594	97.9 (96.5-98.8)		583	98.7 (97.7-99.3)		572	98.2 (96.9-99.0)		554	98.4 (97.2-99.1)	
$80,001 - $120,000	502	99.7 (98.6-99.9)		475	98.8 (97.2-99.4)		406	98.8 (97.3-99.4)		435	99.4 (97.6-99.9)	
$120,001 or more	438	100.0		452	99.9 (99.4-100.0)		530	100.0		582	99.6 (98.3-99.9)	
Not stated	767	95 (92.9-96.4)		793	95.1 (93.5-96.3)		909	95.8 (94.0-97.1)		748	96.4 (94.6-97.6)	
Employment status												
Fulltime employed	1122	99.2 (98.0-99.7)	<0.001	1161	99.1 (98.5-99.5)	<0.001	1107	99.3 (98.6-99.7)	<0.001	1016	99.1 (98.3-99.5)	<0.001
Parttime employed	582	99.4 (97.7-99.8)		573	98.4 (97.2-99.1)		549	99.2 (98.2-99.7)		586	99.2 (98.1-99.7)	
Home Duties	192	94.4 (90.7-96.7)		166	99.0 (96.7-99.7)		203	96.6 (93.1-98.3)		158	98.2 (95.2-99.3)	
Unemployed	65	99.0 (93.2-99.9)		88	98.0 (93.6-99.4)		88	98.5 (94.2-99.6)		95	99.0 (95.8-99.8)	
Retired	482	79.3 (76.1-82.3)		486	79.7 (76.8-82.3)		536	87.3 (84.8-89.5)		514	86.7 (84.2-88.9)	
Student	287	98.4 (94.1-99.6)		239	99.3 (95.1-99.9)		328	99.4 (96.0-99.9)		273	99.1 (95.8-99.8)	
Other/not working due to health	143	89.0 (81.8-93.5)		155	94.7 (91.4-96.8)		133	92.6 (88.9-95.2)		157	96.6 (93.3-98.3)	
SEIFA IRSD quintile												
Lowest (most disadvantaged)	657	91.8 (88.2-94.5)	0.001	683	94.8 (93.3-95.9)	0.015	714	95.2 (92.8-96.8)	0.113	630	95.1 (93.0-96.5)	0.015
Low	453	93.3 (90.6-95.2)		565	92.8 (90.5-94.6)		495	96.5 (94.8-97.6)		572	95.4 (93.9-96.5)	
Middle	588	94.6 (92.7-96.0)		506	95.0 (93.0-96.5)		529	96.0 (94.4-97.1)		490	96.5 (94.8-97.7)	
High	526	94.3 (92.3-95.8)		485	94.6 (92.7-96.0)		536	96.6 (94.8-97.8)		525	96.7 (95.2-97.8)	
Highest (least disadvantaged)	648	97.6 (96.4-98.4)		636	96.8 (95.1-97.9)		671	97.7 (96.5-98.5)		584	98.2 (96.5-99.1)	

Supplementary Table 3: Proportion of respondents living in households with at least one mobile telephone by sociodemographic variables, 15 years and over (cont.)

	2010 % (95% CI)	p value	2011 % (95% CI)	p value	2012 % (95% CI)	p value	2013 % (95% CI)	p value
Dwelling status								
Owned or being purchased							2082 96.3 (95.3-97.1)	<0.001
Rent from state government (public housing)							128 91.2 (87.2-94.1)	
Rent privately							553 98.3 (96.9-99.1)	
Other							23 89.9 (73.1-96.7)	
Overall	2873 94.3 (93.2-95.3)		2875 94.8 (94.1-95.5)		2944 96.4 (95.6-97.0)		2801 96.3 (95.5-97.0)	

Supplementary Table 4: Proportion of respondents living in households with a directory-listed telephone number (EWP) by sociodemographic variables, 15 years and over

	2010 % (95% CI)	p value	2011 % (95% CI)	p value	2012 % (95% CI)	p value	2013 % (95% CI)	p value
Sex								
Male	878 59.0 (55.9-62.0)	0.153	819 55.2 (51.9-58.5)	0.55	761 51.0 (47.9-54.2)	0.099	716 50.5 (46.0-55.0)	0.439
Female	958 61.8 (58.8-64.7)		872 56.4 (53.4-59.4)		852 54.6 (51.6-57.5)		724 48.7 (45.0-52.5)	
Age (years)								
15 to 24	216 42.6 (36.6-48.8)	<0.001	200 39.7 (33.5-46.2)	<0.001	176 36.2 (30.5-42.2)	<0.001	141 30.4 (23.7-38.0)	<0.001
25 to 34	189 39.9 (34.7-45.4)		149 31.5 (26.4-37.1)		141 30.0 (25.2-35.1)		85 18.9 (14.7-24.0)	
35 to 44	301 58.6 (53.6-63.5)		232 45.4 (40.5-50.4)		219 43.4 (38.5-48.5)		208 43.4 (38.3-48.6)	
45 to 54	324 61.8 (57.2-66.2)		326 62.5 (57.3-67.5)		299 57.1 (51.8-62.1)		277 55.4 (49.8-60.9)	
55 to 64	334 74.2 (69.8-78.1)		326 72.5 (68.2-76.5)		292 62.8 (58.6-66.9)		289 65.2 (60.8-69.3)	
65 to 74	266 83.9 (80.0-87.2)		252 77.0 (72.2-81.2)		299 82.7 (79.1-85.8)		255 73.8 (68.8-78.3)	
75+	206 81.3 (76.3-85.4)		206 85.1 (80.6-88.8)		187 78.2 (72.1-83.3)		186 82.6 (76.7-87.3)	

Supplementary Table 4: Proportion of respondents living in households with a directory-listed telephone number (EWP) by sociodemographic variables, 15 years and over (cont.)

	2010			2011			2012			2013		
		% (95% CI)	p value		% (95% CI)	p value		% (95% CI)	p value		% (95% CI)	p value
Area of residence												
Metropolitan	1331	59.3 (57.1-61.5)	0.229	1216	54.4 (51.8-56.9)	0.108	1191	52.7 (50.1-55.2)	0.793	1047	48.5 (44.4-52.6)	0.254
Regional	505	63.6 (56.9-69.8)		476	60.0 (53.6-66.1)		423	53.3 (49.1-57.6)		393	52.9 (46.3-59.3)	
Number of people in household												
1	234	58.6 (54.8-62.3)	0.118	218	51.9 (48.0-55.9)	0.545	210	51.9 (46.7-57.0)	0.931	176	47.3 (42.2-52.4)	0.248
2	1005	63.0 (59.9-66.0)		880	56.4 (53.6-59.2)		853	53.5 (50.9-56.0)		765	50.5 (46.7-54.2)	
3	331	57.1 (51.9-62.0)		283	56.2 (50.3-61.9)		286	52.8 (47.0-58.6)		237	46.4 (41.1-51.7)	
4 or more	265	57.4 (50.2-64.3)		311	56.9 (50.1-63.5)		264	51.7 (45.0-58.4)		262	52.0 (45.4-58.5)	
Country of birth												
Australia	1402	61.8 (59.1-64.5)	<0.001	1255	56.6 (53.7-59.4)	<0.001	1217	53.7 (51.3-56.1)	<0.001	1108	51.9 (47.7-56.1)	<0.001
UK or Ireland	184	68.9 (63.0-74.3)		175	61.4 (55.3-67.2)		181	53.2 (47.0-59.3)		148	50.5 (44.4-56.5)	
Europe	92	61.7 (53.6-69.3)		101	64.3 (56.9-71.1)		77	63.5 (54.9-71.3)		88	59.7 (51.7-67.3)	
Asia	56	35.8 (28.0-44.5)		91	38.0 (30.8-45.7)		65	33.2 (24.9-42.6)		56	27.0 (20.8-34.2)	
Other	101	51.6 (42.4-60.7)		70	53.6 (43.9-63.1)		72	56.5 (46.0-66.4)		41	33.1 (24.0-43.8)	
Aboriginal / Torres Strait Islander												
No	1815	60.8 (58.4-63.0)	0.018	1674	56.3 (53.9-58.7)	0.006	1585	53.5 (51.3-55.6)	0.001	1420	50.4 (46.9-53.9)	<0.001
Yes	16	35.9 (22.3-52.1)		16	30.0 (16.1-48.9)		21	27.8 (17.9-40.6)		11	15.9 (9.1-26.3)	
Household structure												
Couple family children	685	64.1 (60.2-67.8)	<0.001	644	55.9 (51.8-59.9)	<0.001	584	53.4 (49.4-57.3)	<0.001	538	51.3 (46.6-56.0)	<0.001
One parent family, other	162	46.8 (41.0-52.7)		109	37.0 (30.6-43.8)		121	40.7 (35.1-46.7)		105	31.4 (26.3-37.0)	
Lone adult person	214	60.3 (56.1-64.4)		200	54.6 (50.5-58.7)		196	55.1 (49.8-60.3)		160	51.0 (46.2-55.8)	
Couple with no children	550	69.8 (66.7-72.8)		537	67.2 (63.5-70.6)		535	62.6 (59.4-65.6)		446	62.9 (58.6-67.1)	
Other	225	46.8 (40.9-52.9)		201	48.3 (41.9-54.7)		176	39.3 (33.1-45.9)		191	38.4 (32.3-44.9)	

Supplementary Table 4: Proportion of respondents living in households with a directory-listed telephone number (EWP) by sociodemographic variables, 15 years and over (cont.)

	2010			2011			2012			2013		
		% (95% CI)	p value		% (95% CI)	p value		% (95% CI)	p value		% (95% CI)	p value
Marital status												
Married/defacto	1261	66.2 (63.8-68.5)	<0.001	1127	60.3 (57.5-63.0)	<0.001	1101	57.8 (55.2-60.3)	<0.001	998	55.7 (51.9-59.5)	<0.001
Separated/Divorced	126	58.4 (52.0-64.6)		125	51.0 (45.1-56.9)		112	43.1 (37.9-48.4)		126	47.7 (42.9-52.5)	
Widowed	130	72.2 (65.7-77.8)		120	74.6 (68.7-79.7)		129	73.2 (67.4-78.3)		91	68.7 (57.9-77.9)	
Never married	319	43.6 (38.6-48.7)		319	42.5 (37.6-47.6)		269	38.0 (33.2-43.0)		226	31.6 (26.6-37.0)	
Educational attainment												
Secondary schooling	820	59.5 (56.2-62.8)	0.364	693	55.6 (52.0-59.2)	0.341	662	53.0 (49.8-56.1)	0.468	568	48.0 (42.6-53.4)	0.23
Trade, certificate, diploma	638	62.1 (58.6-65.4)		670	57.7 (54.0-61.2)		597	53.4 (50.0-56.8)		557	52.6 (49.1-56.0)	
Bachelor degree or higher	377	59.9 (55.8-63.9)		326	52.9 (48.3-57.4)		354	51.9 (47.7-56.1)		311	47.7 (41.9-53.6)	
Gross annual household income												
Up to $20,000	169	62.0 (55.3-68.3)	0.398	170	62.7 (56.8-68.2)	0.103	130	54.8 (49.5-60.0)	0.367	86	49.6 (43.0-56.1)	0.002
$20,001 - $40,000	257	62.9 (57.1-68.3)		244	61.0 (55.6-66.1)		200	58.3 (53.3-63.1)		229	61.5 (56.3-66.5)	
$40,001 - $80,000	366	60.3 (56.0-64.5)		313	53.1 (48.1-58.0)		306	52.6 (48.1-57.0)		266	47.4 (42.5-52.3)	
$80,001 - $120,000	301	59.8 (55.1-64.2)		258	53.7 (48.0-59.2)		207	50.4 (44.9-55.8)		223	51.0 (44.8-57.2)	
$120,001 or more	278	63.6 (58.6-68.3)		253	55.8 (50.4-61.1)		279	52.7 (47.6-57.6)		279	47.7 (42.0-53.4)	
Not stated	464	57.4 (53.0-61.8)		454	54.4 (49.4-59.3)		491	51.8 (47.7-55.8)		357	46.2 (40.2-52.3)	

Supplementary Table 4: Proportion of respondents living in households with a directory-listed telephone number (EWP) by sociodemographic variables, 15 years and over (cont.)

	2010	% (95% CI)	p value	2011	% (95% CI)	p value	2012	% (95% CI)	p value	2013	% (95% CI)	p value
Employment status												
Fulltime employed	649	57.4 (54.1-60.6)	<0.001	586	50.0 (46.3-53.7)	<0.001	547	49.1 (45.4-52.7)	<0.001	442	43.1 (38.0-48.5)	<0.001
Parttime employed	353	60.3 (55.7-64.7)		314	53.9 (48.7-59.1)		262	47.4 (42.4-52.4)		301	50.9 (46.5-55.4)	
Home Duties	101	49.8 (42.4-57.3)		64	38.4 (31.3-45.9)		106	50.2 (42.0-58.3)		72	44.9 (38.0-52.1)	
Unemployed	25	37.9 (25.7-51.8)		37	41.1 (29.9-53.4)		27	31.1 (20.5-44.2)		34	36.0 (22.9-51.5)	
Retired	485	80.0 (76.6-82.9)		483	79.3 (76.0-82.3)		471	76.9 (73.7-79.9)		447	75.6 (71.3-79.4)	
Student	146	50.1 (42.1-58.1)		111	46.2 (36.6-56.1)		134	40.7 (33.7-48.2)		81	29.3 (21.6-38.4)	
Other/not working due to health	77	49.7 (39.3-60.0)		93	57.2 (49.1-64.9)		65	45.8 (38.4-53.4)		62	38.7 (31.7-46.2)	
SEIFA IRSD quintile			0.01			<0.001			0.162			0.072
Lowest (most disadvantaged)	378	53.4 (47.6-59.1)		369	51.2 (45.4-57.0)		379	50.7 (46.6-54.7)		289	43.7 (37.6-50.0)	
Low	298	61.5 (57.4-65.5)		297	48.9 (44.3-53.5)		273	53.4 (47.8-58.8)		279	46.5 (41.9-51.2)	
Middle	385	62 (57.4-66.5)		304	57.2 (51.3-62.9)		274	49.8 (45.1-54.5)		263	51.8 (44.0-59.6)	
High	348	62.3 (57.2-67.1)		302	58.8 (53.7-63.8)		291	52.5 (47.3-57.7)		284	52.3 (44.7-59.8)	
Highest (least disadvantaged)	426	64.1 (60.4-67.7)		420	63.9 (59.2-68.4)		395	57.6 (52.7-62.2)		327	54.9 (50.0-59.8)	
Dwelling status												
Owned or being purchased										1276	59.0 (55.4-62.6)	<0.001
Rent from state government (public housing)										46	33.6 (25.6-42.6)	
Rent privately										105	18.7 (15.1-23.0)	
Other										11	43.1 (25.7-62.5)	
Overall	1836	60.4 (58.1-62.7)		1692	55.8 (53.4-58.2)		1613	52.9 (50.7-55.0)		1440	49.6 (46.1-53.1)	

Chapter 4: Does declining participation over the last 12 years indicate that household telephone surveys are no longer representative?

4.1 Statement of Authorship

Title of Paper	Does declining participation over the last 12 years indicate that household telephone surveys are no longer representative?
Publication Status	☐ Published ☐ Accepted for Publication ☑ Submitted for Publication ☐ Unpublished and Unsubmitted work written in manuscript style
Publication Details	Submitted to sociological Methods and Research, May 2016

Name of Principal Author (Candidate)	Eleonora Dal Grande
Contribution to the Paper	Participated in the design and co-ordination of the study, performed statistical analyses, and drafted and revised the manuscript.
Overall percentage (%)	80%
Certification:	This paper reports on original research I conducted during the period of my Higher Degree by Research candidature and is not subject to any obligations or contractual agreements with a third party that would constrain its inclusion in this thesis. I am the primary author of this paper.
Signature	Date 15/6/2016

Name of Co-Author	Catherine R. Chittleborough
Contribution to the Paper	Participated in the design and co-ordination of the study, advice on analyses, and was involved in the drafting and revising of the manuscript. I give permission for Eleonora Dal Grande to present this paper for examination towards the doctor of Philosophy.
Signature	Date 6/6/2016

Name of Co-Author	Stefano Campostrini
Contribution to the Paper	Participated in the design and co-ordination of the study, advice on analyses, and was involved in the drafting and revising of the manuscript. I give permission for Eleonora Dal Grande to present this paper for examination towards the doctor of Philosophy.
Signature	Date 10/6/2016

Name of Co-Author	Anne W. Taylor
Contribution to the Paper	Participated in the design and co-ordination of the study, advice on analyses, and was involved in the drafting and revising of the manuscript. I give permission for Eleonora Dal Grande to present this paper for examination towards the doctor of Philosophy.
Signature	Date 15/6/2016

4.2 Abstract

Participation in telephone surveys have been declining. This study examines the trend of nonresponse in a cross-sectional, monthly chronic disease and behavioural risk factor surveillance system of all ages in Australia from 2002 to 2014 by analysing the trend in the sociodemographic characterises and the response, refusal and corporation rates. The samples were selected from a listed landline-based telephone directory. Response rates decreased by 18.6% and refusal rates increased by 65.5% over this period. When compared to the Australian Census, the surveillance system had a higher proportion of females and older people which increased over time, and a lower proportion of people who were employed and rented, which decreased over time. These findings support the need to incorporate under-represented sociodemographic groups into survey adjustments or identify alternative sampling techniques.

4.3 Background

Many chronic disease and behavioural risk factor surveillance systems use probability-based, repeated, cross-sectional population telephone surveys to monitor the prevalence of health conditions and the associated risk factors to provide timely data for health professional and planners of health services[6, 9]. Probability-based sampling methods are used to produce non-biased estimates in order to make inferences about the population of interest[18, 64, 66]. As with all surveys, surveillance systems are subject to sampling errors (sampling design, sample size and survey adjustments) and non-sampling errors (question design, nonresponse, non-coverage, measurement and data processing)[67, 68, 71] that can result in biased survey estimates. Telephone surveys are particularly challenged by the rapid technological changes in telecommunication and societal influences[18, 69], which have contributed to non-sampling biases, specifically, nonresponse and non-coverage[18, 62, 70].

Nonresponse in surveys occurs when the selected respondent does not participate in the survey (unit nonresponse) or does not provide a response to a question (item nonresponse)[64, 71]. Unit nonresponse, described as the failure

to obtain measurements for all the eligible respondents in the sample[64, 71], has been increasing over the years[66, 76, 78-80] and can result in biased estimates[82, 96], increased survey costs[62, 82, 84] and increased variance in post-survey statistical adjustments such as weighting or multiple imputation[90, 162]. Unit nonresponse in telephone surveys has been mainly due to refusal to participate (either by the selected respondent or someone else refusing on their behalf), and inability to establish contact with the selected respondent[77]. As a consequence, nonresponse has the potential for bias in survey estimates.

When the aim of chronic disease and behavioural risk factor surveillance systems is to monitor prevalence of health status and risky behaviours, nonresponse bias is an important issue because the responses from the participants who complete the surveys can result in different estimates from the true prevalence in the population of interest[82, 99]. It has been argued that the driving factors of rising nonresponse in telephone surveys have been influenced by both societal and telecommunication changes over time[18]. The decline in altruism (civic duty) and an increase in the need for privacy and confidentiality has also contributed to the decreasing participation in surveys[86, 89, 163]. In addition, changes in telecommunications over the last 15 years has made it easier for people to screen their calls, with caller ID technology and answering machines assisting with passive refusals[18]. The increased use of the telephone by telemarketers has led to respondent burden such that the community has "survey fatigue"[69, 84, 121]. This effect has been so strong, the effect that in Australia changes in legislation have been imposed on telemarketers with the introduction of the "Do Not Call Register Act" in June 2006, which has also had implications for survey researchers by contributing to the increase in nonresponse in household surveys[84, 121].

It is essential that surveys are examined for nonresponse biases and survey quality using various methods to compare respondents and nonrespondents including information available from the sampling frame used in the survey to ensure that appropriate estimates are obtained[92, 101]. However, many sampling frames, such as the sources used in Australia[103, 107], have limited or

no demographic information about the people who do not respond and general measures such as response rates are the main measures of nonresponse bias and a criteria of survey quality. Despite this use, it is increasingly argued that response rates are not a good indicator of survey quality[70, 82, 90, 92, 96, 98, 101]. A survey with a high response rate does not necessarily have estimates that are more representative of the target population than a sample with a low response rate[164]. Even though the response rates, and other nonresponse rates, are not sufficient to evaluate nonresponse bias, they do provide an initial understanding of the potential biases at the survey level, and comparison between surveys over time[75, 165], and can be informative when used with other analytic approaches[97, 98], as summarised by Halbesleben & Whiteman (2013)[101].

This study assesses the nonresponse biases of an Australian chronic disease and behavioural risk factor surveillance system that utilises the telephone and examines if the representativeness, in terms of demographic characteristics, has been compromised due to declining participation. The sampling frame used is sourced from a directory-list of telephone numbers, referred to as Electronic White Pages (EWP). EWP consists mainly of listed landline telephone numbers and a smaller proportion of mobile and Voice over Internet Protocol (VOIP) telephone numbers with name and address details for a household or business[11, 166]. Telephone numbers can easily be extracted from the EWP by geographical areas (state, suburbs or postcodes); in this case, households in South Australia (around 7% of the total Australian population). However, this sample has no additional sociodemographic information about the household or individual(s) within the household. This study will use surveillance data collected from 2002 to 2014 to examine nonresponse rates over time and the differences in the demographic profile of the respondents compared to Australian Census data[101]. To our knowledge this is the first study in Australia to examine nonresponse of telephone population health surveys over time, and provide insight relating to potential biases that may exist in estimates when using these systems.

4.4 Methods

4.4.1 Survey design and sample selection

Data were collected using the South Australian Monitoring and Surveillance System (SAMSS) from 2002 to 2014. SAMSS is a telephone monitoring system designed to monitor, over time, the health conditions, risk factors and other health service issues in South Australia (SA)[11]. Approximately 600 randomly selected interviews were conducted for all ages each month. Respondents were eligible to participate if they were living in a South Australian household with a telephone number listed in the EWP. A letter introducing the survey was sent to the selected household. Within each household, the person with the last birthday was chosen for interview. There was no replacement for non-respondents. Up to ten call backs were made to the household to interview the selected person. Interviews were conducted by trained health interviewers via the Computer Assisted Telephone Interviewing (CATI) system. Ethical approvals were obtained from the Human Research Ethics Committees of The University of Adelaide and the SA Department of Health. Participants gave verbal informed consent to undertake the telephone interview.

4.4.2 Sociodemographic variables

Sociodemographic variables included in these analyses were sex, age, area of residence, household size, country of birth, marital status, educational attainment, employment status, and dwelling ownership or renting status.

4.4.3 Population data

The population source for comparison purposes was the five-yearly Australian Bureau of Statistics 2001, 2006 and 2011 Census[167]. Nine sociodemographic variables were ascertained for comparison with SAMSS sociodemographic variables. Categories were collapsed where there were differences between SAMSS and the Census of wording or response categories.

4.4.4 Nonresponse rates

Four nonresponse rates, response rates (RR1), cooperation rates (COOP1), refusal rates (REF1) and contact rates (CON1), were calculated from the final dispositions of the telephone numbers using the American Association for Public Opinion Research (AAPOR) standard definitions[75]; each providing a description of different components of the survey. RR were defined as the number of completed interviews divided by the number of eligible respondents in the sample; cooperation rates (COOP) were the number of all completed interviews divided by all eligible respondents ever contacted; refusal rates (REF) were the number of all respondents who refused to be interviewed or terminated an interview, divided by all potentially eligible cases; and contact rates (CON) are the proportion of all cases in which a person within the household was reached. The AAPOR (2011) offers alternative calculations for all four rates based on the survey design and method, and how nonrespondents are treated when their eligibility is unknown, for example, RR has six different calculations. In this study, the minimum rates were used: RR1, COOP1, REF1 and CON1.

4.4.5 Coverage

To understand the possible impact of the sampling frame on the representativeness of the data, an alternative SA data source was used to estimate the coverage of the SAMSS sampling frame[107, 166]. Questions on telephone status within the household have been included in an annual multi-stage, systematic, clustered area, face-to-face population survey, the Health Omnibus Survey (HOS), since 1998[105, 107, 166]. From these questions, the proportion of households that have their landline and/or mobile telephone number listed in the telephone directory was estimated.

4.4.6 Statistical analyses

Data analysis was conducted using SPSS Version 20.0. The median yearly nonresponse rates from SAMSS were calculated for RR1, COOP1, REF1 and

CON1 from 2002 to 2014. The JoinPoint Regression Program (Version 4.2.0), developed by the US National Cancer Institute, was used[168] to describe the changing trends for each nonresponse rate to detect change between years (or joinpoints) and to calculate the annual percentage change for specific segments of time[169]. The coverage rate (proportion of people with a telephone listed) of the sampling frame used in SAMSS was estimated using data from HOS for 2002, 2004, 2005, 2007 and 2010 to 2014.

SAMSS data were weighted by the probability of selection of the respondent within the household and the age and sex, and area of residence (metropolitan/rural) profile of the SA population. Weighted data are used to reduce bias from nonresponse and under-coverage, and improve precision in the survey estimates, however, the weights can have wide variations which can reduce the precision in the survey estimates[170, 171]. To examine the effects of weighting on the sampling errors, the design effect due to weighting was calculated by using[170, 171]

$$weff^2 = n.\frac{\sum w_i^2}{(\sum w_i)^2} = 1 + cv^2\,(w_i)$$

where n is the sample size, w_i is the weighting value for each participants, i (i=1,2, …, n), and cv is the coefficient of variation of the weights.

To examine the magnitude of the nonresponse bias of SAMSS over time for sociodemographic variables, analyses were undertaken for surveys in four year intervals (2002, 2006, 2010 and 2014). The unweighted demographic profile was determined and discrepancies between the unweighted survey data proportion and Census data proportion for all the response categories of that variable were calculated. The index of dissimilarity was calculated over time (2002 to 2014) for nine comparable sociodemographic variables in the survey data and Census data. The index of dissimilarity is described as the proportion of survey respondents that would have to be moved to other categories to make the distribution equal to the Census data[172]. A higher value indicates the survey data are less representative compared to the Census data.

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4.5   Results

From 2002 to 2014, the response rates (RR1) in SAMSS have decreased by 18.6% (68.9% to 56.1%) with refusal rates (REF1) increasing by 65.5% (11.0% to 18.2%) (Figure 4.1). The response rates were consistent from 2002 to 2005 (annual percentage change =1.4, p=0.06), but notably started to decrease between 2005 and 2008 (annual percentage change =-3.2, p=0.03) with the introduction of the Do Not Call Register Act in 2006. JPA also detected a significant decline in response rates between 2012 and 2014 (annual percentage change =-5.6, p=0.01) (Table 4.1). Similarly with the refusal (REF1) and the cooperation rates (COOP1): both were steady (approximately 11% and 80% respectively) until 2005 an overall change of 10 percentage points (annual percentage change =19.3, p=0.09 for REF1 and annual percentage change =-3.6, p=0.12 for COOP1) occurred between 2005 and 2008 and then to remained steady from 2009 to 2014. A different pattern was observed for contact rates (CON1), which remained consistently high at around 90% from 2002 to 2011. However, in 2011 the contact rate started to decline from 90.4% to 81.1% in 2014 (annual percentage change =-3.3, p<0.001). The coverage rate of the sampling frame used was high in 2002 and 2004 (close to 80%), but has declined from 73.8% in 2006 to 44.7% in 2014 (Figure 4.1). Figure 4.1 also shows the design effect of the sample weight, which showed a steady increase from 2004 to 2014.

Figure 4.1: Four median nonresponse rates and median design effect of sample weights from SAMSS; and coverage rate from HOS
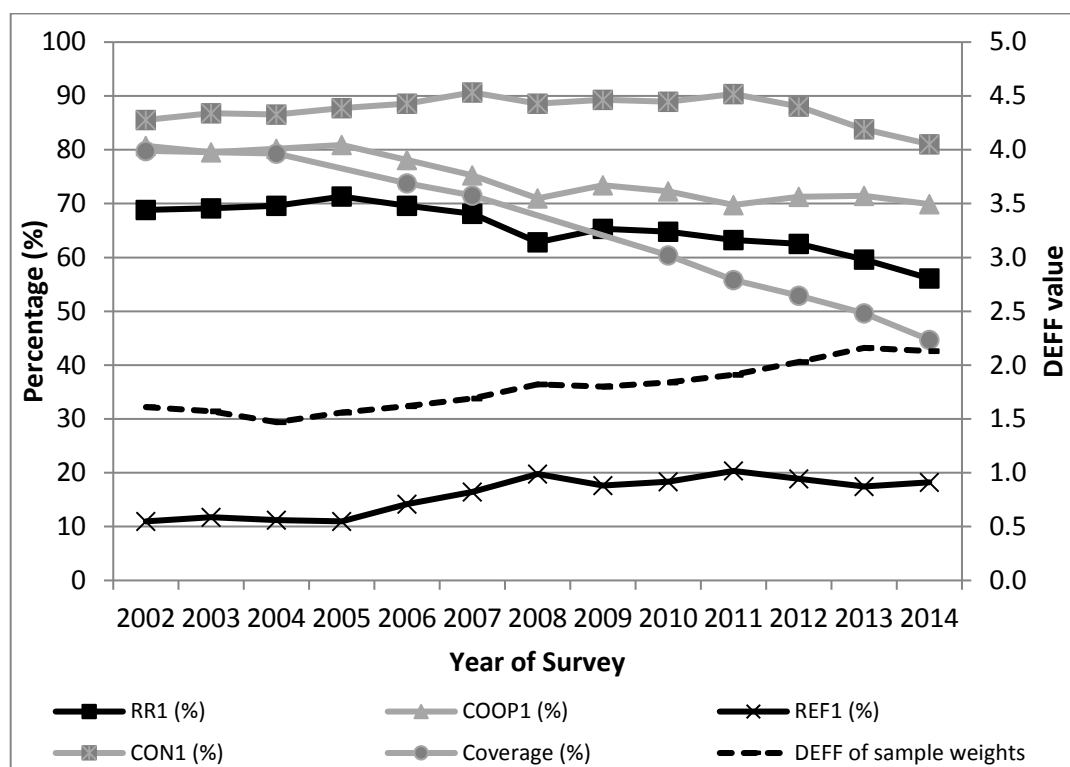
Note: RR response rate; COOP cooperation rate; REF refusal rate; CON contact rate; DEFF design effect; SAMSS South Australia Monitoring and Surveillance System; HOS Health Omnibus Survey

Table 4.2 shows the unweighted sociodemographic profile for the four selected years (2002, 2006, 2010 and 2014), as well as differences between SAMSS and the Census data. SAMSS had a higher proportion of females, people in the older age groups, and people living in rural or remote areas of SA which has increased over time; with most of these differences being over-represented. The proportion of one or two people living in the household has increased over time, whereas households with three or more have decreased, with the trend in the differences with the Census showing mixed results: single person households were under-represented in 2002 but converge to little differences in 2014; three person households were similar to the Census in 2002 but increasingly under-represented over time; and the proportion of people living in a two person household was increasingly overrepresented in SAMSS. There have been relatively minor changes in country of birth in SAMSS over time, however, the proportion of people born in other overseas countries (not UK and Ireland,

or other European countries) has been increasingly under-represented in SAMSS. The proportion of people who work full or part time, and people who rent has decreased, and this group has been increasingly under-represented over time. With the exception of 2010, the proportion of people who were married or in a defacto relationship were over-represented in SAMSS.

Table 4.1: Joinpoint analyses of the four nonresponse rates from SAMSS, 2002 to 2014

	Number of joinpoint	Segments	Annual Percentage Change	95% CI	P value
Response rate (RR1)	3	2002-2005	1.4	0.0 – 2.9	0.06
		2005-2008	-3.2	-5.9 – -0.4	0.03
		2008-2012	-0.7	-0.7 – 0.7	0.11
		2012-2014	-5.6	-8.3 – -2.9	0.01
Cooperation rate (COOP1)	2	2002-2005	0.3	-2.3 – 2.9	0.96
		2005-2008	-3.6	-8.6 – 1.6	0.12
		2008-2014	-0.4	-1.3 – 0.5	0.12
Refusal rate (REF1)	2	2002-2005	0.5	-9.6 – 11.8	0.93
		2005-2008	19.3	-3.6 – 47.6	0.09
		2008-2014	-1.1	-4.6 – 2.5	0.41
Contact rate (CON1)	2	2002-2007	0.9	0.5 – 1.3	0.01
		2007-2011	0.2	-0.8 – 1.1	0.88
		2011-2014	-3.3	-4.2 – -2.4	<0.001

Note: CI Confidence interval

The median yearly index of dissimilarity values, from 2002 to 2014, was calculated for each demographic variable (Figure 4.2). The sociodemographic variables that had categories that were either over- or under-represented, with the highest index values, and almost doubling over time, were age (17.4% in 2002 to 31.6% in 2014), employment status (8.5% in 2002 to 19.8% in 2014) and dwelling status (10.2% in 2002 to 16.4% in 2014). The other sociodemographic variables had relatively low index of dissimilarity values (below 10) over time.

Figure 4.2: Median yearly Index of dissimilarity, SAMSS compared to SA Census, 2002 to 2014
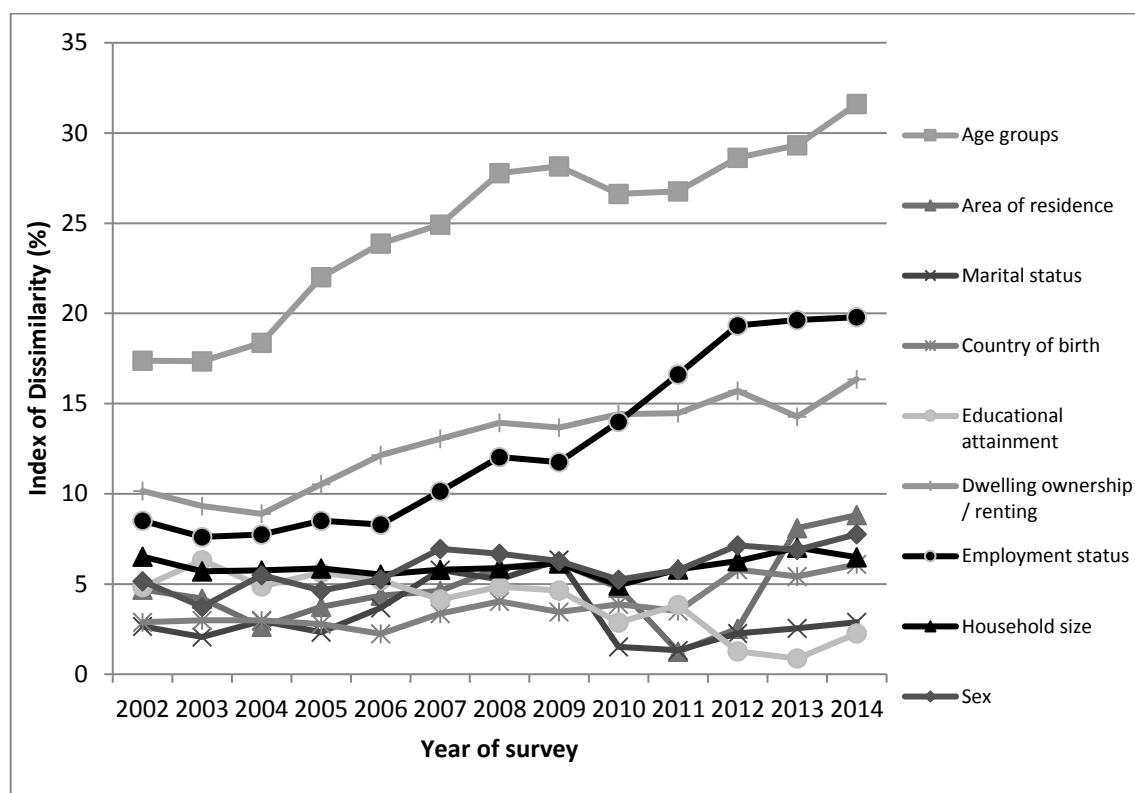
Table 4.2: Unweighted demographic profile of respondents and proportion differences between Census and SAMSS, by selected years (2002, 2006, 2010 and 2014)

| | SAMSS | | | | | | | | Differences with South Australian Census | | | |
| | 2002 | | 2006 | | 2010 | | 2014 | | 2002[b] | 2006[c] | 2010[d] | 2014[d] |
	n	%	n	%	n	%	n	%	%	%	%	%
Sex												
Male	1347	44.5	3129	43.8	4613	44.0	3036	41.9	-5.2	-5.3	-5.2	-7.8
Female	1681	55.5	4013	56.2	5878	56.0	4210	58.1	5.2	5.3	5.2	7.8
Age (years)												
0 to 9	225	7.4	442	6.2	837	8.0	482	6.7	-5.3	-5.9	-4.0	-5.2
10 to 15	172	5.7	312	4.4	608	5.8	386	5.3	-0.9	-2.2	-0.8	-0.8
16 to 24	246	8.1	480	6.7	857	8.2	455	6.3	-5.1	-6.7	-5.1	-6.8
25 to 34	318	10.5	547	7.7	473	4.5	265	3.7	-3.3	-5.3	-7.8	-9.0
35 to 44	390	12.9	808	11.3	779	7.4	513	7.1	-2.3	-3.4	-7.1	-6.5
45 to 54	478	15.8	1152	16.1	1418	13.5	801	11.1	1.7	2.0	-0.8	-3.0
55 to 64	454	15.0	1338	18.7	2177	20.8	1476	20.4	5.1	7.6	9.1	7.9
65 to 74	373	12.3	1025	14.4	1744	16.6	1560	21.5	4.7	6.9	9.0	13.2
75+	372	12.3	1038	14.5	1598	15.2	1308	18.1	5.3	7.0	7.4	10.3
Area of residence												
Metropolitan	2092	69.1	4791	67.1	7047	67.2	4583	63.2	-4.7	-4.4	-4.8	-8.8
Regional	936	30.9	2351	32.9	3444	32.8	2663	36.8	4.7	4.4	4.8	8.8
Number of people in household												
1	678	22.4	1722	24.1	2572	24.5	1930	26.6	-5.0	-4.1	-3.1	0.3
2	1116	36.9	2740	38.4	4139	39.5	2972	41.0	3.2	4.2	4.0	6.5
3	437	14.4	966	13.5	1394	13.3	880	12.1	-0.4	-1.7	-1.5	-3.8
4 or more	797	26.3	1714	24.0	2386	22.7	1464	20.2	3.3	1.8	1.0	-3.0
Country of birth												
Australia	2375	78.4	5656	79.2	8337	79.5	5709	78.8	0.2	0.2	1.0	2.5
UK or Ireland	355	11.7	744	10.4	1117	10.6	834	11.5	2.5	1.1	2.1	3.4
Europe	194	6.4	478	6.7	644	6.1	429	5.9	-0.6	-0.2	-0.1	0.7
Other	104	3.4	264	3.7	393	3.7	274	3.8	-1.7	-1.4	-2.7	-5.7

Table 4.2: Unweighted demographic profile of respondents and proportion differences between Census and SAMSS, by selected years (2002, 2006, 2010 and 2014) (continue)

	SAMSS								Differences with South Australian Census			
	2002		2006		2010		2014		2002[b]	2006[c]	2010[d]	2014[d]
	n	%	n	%	n	%	n	%	%	%	%	%
Marital status[a]												
Married/defacto	1552	59.0	3824	59.9	5101	56.5	3637	57.1	2.7	3.7	0.9	2.9
Separated, Divorced, Widowed, Never married	1077	41.0	2558	40.1	3927	43.5	2727	42.9	-2.7	-3.7	-0.9	-2.9
Educational attainment[a]												
Secondary schooling, trade, certificate, diploma	2180	82.9	5257	82.3	7453	82.4	5100	80.0	-4.8	-5.2	-2.9	-2.3
Bachelor degree or higher	451	17.1	1131	17.7	1593	17.6	1278	20.0	4.8	5.2	2.9	2.3
Employment status[a]												
Fulltime employed	928	35.3	2231	34.9	1731	27.6	1611	25.3	-3.9	-3.2	-10.3	-12.8
Parttime employed	393	14.9	982	15.4	1051	16.8	1044	16.4	-3.2	-2.7	-2.4	-5.4
Unemployed	64	2.4	117	1.8	109	1.7	131	2.1	-2.3	-2.7	-0.9	-1.5
Home Duties, student, retired, unable to work	1246	47.4	3058	47.9	3372	53.8	3592	56.3	8.5	8.3	14.0	19.8
Dwelling status												
Rent	478	15.8	964	13.5	1291	12.3	843	11.6	-10.2	-12.1	-14.4	-16.4
Owned or being purchased, other	2550	84.2	6178	86.5	9200	87.7	6403	88.4	10.2	12.1	14.4	16.4

Notes: a -16 years and over; b 2001 Census; c 2006 Census; d 2011 Census

4.6 Discussion

This study has confirmed previous findings that response rates should not be used as sole measures of data quality[82, 94-96] and that examination of the respondents, including sociodemographic characteristics, should be used to assess potential biases in the estimates. Response rates for a chronic disease and behavioural risk factor surveillance system utilising the telephone in SA have decreased by 18.5% over a 12 year period. The last four years has shown the contact rate decreasing from 90.4% to 81.1% compared to the previous nine years of relatively high and stable rates of around 90%, inferring that people are refusing to participate but perhaps in a more passive manner. As nonresponse rates change over time, some sociodemographic groups are increasingly being either over-estimated (older people, females, retirees) or under-represented (younger people, males, full-time workers, rented accommodation). This indicates that SAMSS is potentially becoming less representative over time and consequently may be producing biased estimates.

This is one of the few studies in Australia that has examined trends in participation (nonresponse rates) and representativeness in telephone surveys based on sociodemographic characteristics of participants collected in surveillance systems. The response rates in this study are higher than other comparable studies using the telephone within Australia[103, 116] but similar to response rates in Western Australia[173]. However, the annual average decrease in response rates of 1.6% follows the trend of other surveillance systems with similar methodology[77, 165, 174]. Comparison of response rates across Australian telephone surveys is difficult as there are no recognised standards in Australia, response rates formulas are often not reported or justified, thus potentially misleading or inflated rates may be reported[49, 50]. The use of standardised formulas, such as the AAPOR, allow easy comparison and understanding of response rates.

Our findings demonstrate an increase in refusal rates between 2005 and 2008, and a decrease in response rates between 2005 and 2008 corresponding to the

introduction of the Do Not Call Registry in 2006. This finding contradicts the study by Link et al[175] in which there was no impact on response rates with the introduction of the American Do Not Call Registry in 2003. Even though research studies such as SAMSS are exempt from the Do Not Call Registry in Australia, the introduction of the registry may have raised awareness in the community of their right to say 'no' to surveys, increasing the proportion feeling comfortable in refusing to participate.

This study has also demonstrated that using a reliable external source, such as the Census, and simple functions, such as the index of dissimilarity, can provide information on the performance and representativeness of surveys over time. The suite of alternative approaches recommended by Groves et al[96] could not all be undertaken since there are no available demographic information on nonresponders. Some studies have examined nonresponse bias by examining area-level data of nonrespondents from the sampling frame and respondents, such as postcode, and analyse the associated sociodemographic information by postcode from the Census[88, 176]. Other studies have compared early or easy and late or difficult respondents, with the assumption that late or difficult respondents are similar to nonrespondents[92, 94, 177]. Schouten et al[99] have developed a suite of alternative indicators, representatively (R) indicators, for this type of study where corresponding information from the Census can be used, but unfortunately the software program was not available for this study (communication with Schouten). We are watching this area with interest. These alternative approaches could be considered for future research on data collection by incorporating additional resources, questions and retaining additional CATI systems information.

The widening gap between males and females, young and older participants, unemployed or employed and home duties, student, retired or unable to work, and people who rent and own their own homes, may introduce biased estimates in prevalence of health indicators. The increasing gaps in males and females and age groups are reflected in increasing values of the design effect of the weighting variable over time. Our study has also shown the coverage rate of our sampling

frame from the external face-to-face survey, Health Omnibus Survey, is also decreasing, which can explain the increasing index of dissimilarity for age, dwelling status (renters, home owner) and employment status. These findings are supported by a recent SA study[166] and other studies[146, 155, 178, 179] that reported that people who do not have their telephone number listed in the directory were more likely to be younger, living in the metropolitan area, never married, separated or divorced, bachelor degree or higher, unemployed, and renting, and the disparities between the groups is increasing over time. Therefore, other methods are needed to reduce the biases in the estimates to account for the groups that are under-represented in SAMSS.

Many studies have examined different techniques in dealing with nonresponse and nonrepresentativeness using different survey modes or mixed-method studies[103, 116], or various statistical adjustments such as weighting[65, 90, 91, 180]. Studies in the USA and Australia have shown that using statistical adjustments such as raked weights methodology can reduce the biases in the health and behavioural risk factor estimates by incorporating a range of sociodemographic variables that are known to be under-represented, in telephone surveys, such as employment and dwelling status, besides the usual age and sex[134, 140, 181, 182]. Work undertaken in SA has demonstrated that using raked weighting methodology to adjust for specific groups of the community (for example, people who rent) who are increasingly being under-represented resulted in health estimates more in line with the more expensive national and state-based face-to-face surveys[181]. Biases induced by lower response rates should be tackled with more sophisticated approaches. Incorporating a few sociodemographic variables, such as age and sex, in the weighting for telephone surveys is not sufficient and may lead to biased estimates[182]. Sociodemographic variables such as dwelling status and employment should be collected in telephone surveys, not solely to be used as covariates, but as essential information for statistical adjustments in weighting or analyses, to maintain representativeness in the estimates.

It should be acknowledged that this paper has focused on one area of bias in epidemiological surveys, namely, unit nonresponse. There are many other types of bias that are beyond the scope of this paper, including survey mode differences, question design, interviewer bias, socially desirable responses, and sensitive topics. These are covered in more detail elsewhere[58, 61, 83]. Thus, a survey with a higher response rate or one is that more representative does not necessarily mean better quality data if the survey has poorly designed questions, or other sources of bias.

A strength of this study is the long period of monthly repeated surveys to allow trend analysis, and the consistency in sociodemographic questions used over this period and the availability of data from a geographical matched face-to-face survey. A limitation is that not all sociodemographic variables or categories could be compared to the Census data because the wording of the question or categories were not comparable for example, the categories in marital status, or the proportion of missing data was too high in both data sources (household income).

With falling response rates and coverage of the sampling frame, and increasing refusals and non-contact rates, researchers need to find innovative ways to improve participation in telephone surveys, in particular, to target those groups that are under-represented. Additionally, telephone surveys need to apply more sophisticated statistical adjustments, such as raked weights, which incorporate a wider range of sociodemographic variables, and which have shown an improvement in the accuracy of the health estimates[15, 134, 140, 181]. However, given that the magnitude of the under- or over-represented populations are increasing over time, coupled with the decreasing coverage of the sampling frame, it is apparent that that statistical adjustments may not be sufficient and other alternative sampling methods may be needed in the future.

Chapter 5: Publication - Health estimates using survey raked-weighting techniques in an Australian population health surveillance system

5.1 Statement of Authorship

Title of Paper	Health Estimates Using Survey Raked-Weighting Techniques in an Australian Population Health Surveillance System
Publication Status	☑ Published ☐ Accepted for Publication ☐ Submitted for Publication ☐ Unpublished and Unsubmitted work written in manuscript style
Publication Details	American Journal of Epidemiology; 2015;182(6):544-556

Name of Principal Author (Candidate)	Eleonora Dal Grande		
Contribution to the Paper	Participated in the design and co-ordination of the study, performed statistical analyses, and drafted and revised the manuscript.		
Overall percentage (%)	85%		
Certification:	This paper reports on original research I conducted during the period of my Higher Degree by Research candidature and is not subject to any obligations or contractual agreements with a third party that would constrain its inclusion in this thesis. I am the primary author of this paper.		
Signature		Date	15/6/2016

Name of Co-Author	Catherine R. Chittleborough		
Contribution to the Paper	Participated in the design and co-ordination of the study, advice on the analyses, and was involved in the drafting and revising of the manuscript. I give permission for Eleonora Dal Grande to present this paper for examination towards the doctor of Philosophy.		
Signature		Date	6/6/2016

Name of Co-Author	Stefano Campostrini		
Contribution to the Paper	Participated in the design and co-ordination of the study, advice on the analyses, and was involved in the drafting and revising of the manuscript. I give permission for Eleonora Dal Grande to present this paper for examination towards the doctor of Philosophy.		
Signature		Date	10/6/2016

Name of Co-Author	Graeme Tucker		
Contribution to the Paper	Provided advice on the analyses, and was involved in the drafting and revising of the manuscript. I give permission for Eleonora Dal Grande to present this paper for examination towards the doctor of Philosophy.		
Signature		Date	16/5/2016

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Contribution to the Paper	Participated in the design and co-ordination of the study, advice on the analyses, and was involved in the drafting and revising of the manuscript.
	I give permission for Eleonora Dal Grande to present this paper for examination towards the doctor of Philosophy.
Signature	Date 15/6/2016

5.2 Abstract

A challenge for population health surveillance systems using telephone methodologies is to maintain representative estimates as response rates decrease. Raked weighting, rather than conventional poststratification methodologies, has been developed to improve representativeness of estimates produced from telephone-based surveillance systems by incorporating a wider range of sociodemographic variables using an iterative proportional fitting process. This study examines this alternative weighting methodology with the monthly South Australian population health surveillance system report of randomly selected people of all ages in 2013 (n = 7,193) using computer-assisted telephone interviewing. Poststratification weighting used age groups, sex, and area of residence. Raked weights included an additional six variables: dwelling status, number of people in household, country of birth, marital status, educational level, and highest employment status. Most prevalence estimates (e.g., diabetes and asthma) did not change when raked weights were applied. Estimates that changed by at least two percentage points (e.g., tobacco smoking and mental health conditions) were associated with socioeconomic circumstances, such as dwelling status, which were included in the raked-weighting methodology. Raking methodology has overcome, to some extent, nonresponse bias associated with the sampling methodology by incorporating lower socioeconomic groups and those who are routinely not participating in population surveys into the weighting formula.

5.3 Background

Chronic disease and behavioral risk factor surveillance systems have been established in many countries, including Australia[11-13, 46-48], as a response to the rising prevalence of chronic diseases and the contributing preventable lifestyle factors[4, 23]. To be effective and valuable, the system must be quick, relatively inexpensive, flexible, representative, population based, continuous, and with independent samples drawn at each time period[10, 183]. Because of these requirements, many systems use telephone surveys based on computer-assisted telephone-interviewing technology[5, 11-17, 47, 142].

In the last decade, telephone surveys have undergone many changes because of nonresponse and non-coverage[17, 62, 90], with a resultant potential loss in the precision of survey estimates. *Nonresponse* can be defined as "the failure to obtain a valid response from a sampled unit" (p. 329)[90] and is usually measured by response rates [75]. Response rates have been declining in population surveys of all modes: face-to-face, mail, online, and telephone surveys[85]. Reasons for falling response rates are the increasing proportion of people not willing to participate in surveys of any kind and the inability to establish contact with potential participants[85, 90]. *Non-coverage* can be defined as "the proportion of the target population not covered by the sampling frame" (p. 55)[66]. The majority of telephone surveys in Australia rely on sampling frames that consist mainly of landline telephone numbers[12, 13, 16, 59, 103, 107]. Over the past decade, nationally and internationally, society has moved away from the traditional landline telephones to flexible communications, such as the mobile telephone[17, 51, 52, 62, 104, 105, 107, 109]. This transition is associated with an increase in mobile-only households. In Australia, this has implications for telephone surveys because of the difficultly of obtaining a sample of mobile telephone numbers with a geographical location, such as postcode or state. Australian data from 2011 have estimated that 22% of households are mobile only, which is an increase of over 75% since 2006 (5.2%)[109]. More importantly, this group is not uniformly distributed in the population[107, 146]. These mobile-only households result in specific groups being excluded from the traditional sampling frames used for telephone surveys. These include younger people and

people who are unemployed, rent their housing, and reside in low socioeconomic areas[17, 51, 52, 62, 86, 103-105, 107, 109, 113]. This is compounded in most countries by the difficulty in obtaining a cost-effective and efficient sampling frame[104, 107] and has led to the declining representativeness of surveillance systems based on telephone survey sampling methodology[62, 142]. Recent debates have questioned the value of representativeness in epidemiologic study designs, particularly those focused on examining the causal effect of exposures or interventions on outcomes[184]. Descriptive studies, where the aim is to estimate the occurrence of a disease or risk factor in a given population, however, are the case for which representativeness is universally supported[185-188].

Various statistical methods have been developed to address and improve the representativeness of the estimates produced from telephone-based surveillance systems due to nonresponse. A common statistical approach is to weight the survey data on the basis of the sociodemographic variables that are under- or over-represented in the sample, such that the proportion of the cases in the sample is adjusted to the population proportion as in the census[17]. Weighting approaches can be seen as a form of imputation, where the weight of the nonresponders is distributed to other similar respondents[91]. These imputation methods are model based and are described in detail elsewhere[83]. Weighting is a technique for adjusting the unit record survey such that the data structure is made similar to the population structure in terms of sociodemographic indicators, such as, age and sex, so that inferences can be made. Weighting by the appropriate variables allows point and parameter estimates generated from survey data (e.g., means, proportions, and regression coefficients) to be unbiased population estimates, and it involves statistically increasing or decreasing the numbers of cases[62, 66]. This means that a weighting value is calculated for each individual who participates in a survey, and that weighting value indicates how much the individual's response will count in a statistical procedure. Weighting values are often represented as a fraction, they have a mean value of 1.0, and the sum of the weighting values usually equals the sample size, is always positive, and is non-zero (e.g., 1.35,

0.75). To illustrate, a participant with a weighting value of 2.0 means that his/her response is counted 2 times compared with a participant with a weighting value of 0.5, which means that his/her response is half a count. Using diabetes prevalence as an example, researchers have found that general population surveys in Australia usually have a higher proportion of older people than younger people participating. Unweighted data indicate that 12.0% of the sample has diabetes, but this estimate is an over-estimation because we have a higher proportion of older people. With weighted data, older respondents have weighting values less than 1.0 and younger respondents have weighting values greater than 1.0; this results in a diabetes prevalence of 7.7% that is more reflective of the population.

The weights are developed in a series of stages. One is to calculate the base weight[189], which is to take into account the complex sampling design and to adjust the data according to the different selection probabilities and the complex sampling design. For example, only 1 eligible person is selected at random within a household to participate[66]. The other part is cell weighting or poststratification adjustments (the focus of this paper) that modify the survey data by particular characteristics so that the proportion of cases in the sample is adjusted to the population proportion, such as census data. The standard *poststratification* weighting (or cell weighting) method adjusts the sample data by creating a cross-classification of categorical variables (e.g., age groups × sex × area of residence × marital status × income) and matches the proportions to population data. However, this method has limitations as each addition of a variable in the cross-tabulations can result in smaller or empty cell sizes that can result in unstable weights. Therefore, only a few variables are usually included, typically, age group, sex, and area of residence.

The US Behavioral Risk Factor Surveillance System (BRFSS) has implemented a statistical technique called *raked weights* or *raking* to address the problem with the *poststratification* weighting method[15, 139]. Raking adjusts the sample data 1 variable at a time by using an iterative proportional fitting process[134, 190]. Changes in some BRFSS health estimates, including prevalence of current

smokers, no physical activity, or perceived health as fair or poor, have resulted when raked weights were applied[15, 134, 140]. However, they have also found that the prevalence of other health conditions, such as diabetes and coronary heart disease, remained the same.

The raking iterative process can be explained by using the following example with 2 variables: age (i.e., 7 age group categories) and sex (2 categories). Starting with age groups, each case is multiplied by the ratio of the population total to the weighted sample total for each age group category. This will result in the age group category totals of the adjusted weighted data agreeing with the population totals. However, the weighted category totals for the sex variable do not agree with its corresponding population category totals. The next step is to take the sex variable and multiply each case by the ratio of the population total to the weighted sample total for each sex group category. Now the new calculated weighted category totals for sex will agree with the population totals for sex. However, the weighted category totals for the age group variable do not agree with its corresponding population category totals, and the calculation is repeated, until the weighted category totals for both age groups and sex agree with the corresponding population category totals.

The challenge for chronic disease and behavioral risk factor surveillance systems utilising the telephone in Australia and similar countries is to ensure that the methodology is effective and efficient in obtaining and providing representative and reliable population data. This raking weighting method has not been applied in Australia but could potentially reduce bias in the estimates from Australian chronic disease and risk factor surveillance systems. It is not known if major differences across weighting methods found in the BRFSS would apply in Australia (with higher responses rates and different ethnicity and socioeconomic distributions). The main objective of this paper is to apply the raking methodology to data from an Australian population health surveillance system and to examine the impact on the estimates produced by use of traditional (cell weighting) and raked weights.

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5.4 Methods

5.4.1 Survey design and sample selection

Data for this study were collected by using the South Australian Monitoring and Surveillance System (SAMSS) in 2013. SAMSS is a telephone-monitoring system designed to monitor, over time, the health conditions, risk factors, and other health service issues in South Australia[11]. Approximately 600 randomly selected interviews were conducted for all ages each month. Households in South Australia with a telephone connected and listed in the telephone directory were eligible. A letter introducing the survey was sent to the selected household. Within each household, the person with the most recent birthday was chosen for interview. There were no replacements for nonrespondents. Up to 10 callbacks were made to the household to interview the selected person. Interviews were conducted by trained health interviewers via a computer-assisted telephone-interviewing system. Ethical approvals were obtained from the human research ethics committees of The University of Adelaide and the South Australia Department of Health. Participants gave verbal informed consent to participate in the telephone interview. A total of 7,193 interviews were conducted in 2013 with a 61.7% response rate.

5.4.2 Sociodemographic variables used for raked-weighting methodology

The population source was the 5-yearly Australian Bureau of Statistics 2011 Census, using TableBuilder Pro[191], which allowed some flexibility in constructing summary data to match with SAMSS demographic questions. Nine sociodemographic variables to be incorporated into the raked-weight methodology were ascertained as suitable and are shown in Table 5.1.

Sociodemographic variables were considered if they had a strong association with various chronic disease and behavioral risk factors or were strongly related to nonresponse or non-coverage. Sociodemographic variables with categories having less than 5% in the sample were not considered, such as Aboriginal/Torres Strait Islander status. Categories were collapsed, or

variables were excluded if there was a high proportion of missing data or difficulties in harmonising the categories or variables between SAMSS and the census because of wording differences.

Table 5.1: Variables Used in Weighting (Poststratification and Raking)

Variable	Categories	Post-stratification Weights	Raked Weights
Sex	Male, female	Yes	Yes
Age groups	0–9, 10–15, 16–34, 35–44, 45–54, 55–64, 65–74, ≥75 years	Yes	Yes
Area of residence	Metropolitan Adelaide, Rural or remote areas	Yes	Yes
Country of birth	Australia, United Kingdom, Europe, other	No	Yes
Dwelling status	Renting, other (owned or being purchased, other)	No	Yes
Marital status (16 years or more)	Married or living with partner, other (widowed, separated, divorced, never married)	No	Yes
Educational level (16 years or more)	Bachelor's degree or higher, other (none to some high school, trade, certificate, diploma)	No	Yes
Employment status (16 years or more)	Full-time employed, part-time employed, unemployed, other (home duties, student, retired, unable to work)	No	Yes
No. of people in the household (including children)	1, 2, 3, 4 or more	No	Yes

5.4.3 Sociodemographic variables used for poststratification weighting

The variables used for poststratification weighting were age groups, sex, and area of residence, as described for raked weights (Table 5.1).

5.4.4 Outcome variables

For respondents aged 16 years or more, self-reported health conditions included overall health status, diabetes, cardiovascular disease (heart attack, angina, heart disease, and/or stroke), arthritis, current asthma[192], chronic obstructive pulmonary disease, and osteoporosis. Having a chronic condition included diabetes, current asthma, cardiovascular disease, arthritis, or osteoporosis. Psychological distress used 10 questions from the Kessler 10 screening scale[193] scored to a single scaled item, where respondents with high scores of 22–50 were categorised as having psychological distress[194]. Having a current mental health condition meant a diagnosis of and/or treatment for anxiety, depression, a stress-related problem, or another mental health problem. Suicidal ideation used 4 items from the 28-item General Health Questionnaire[195] that produced a score ranging from 0 to 4, where a score of 1 or more indicated suicidal ideation[196].

For respondents aged 16 years or more, self-reported health-related risk factors included current or receiving treatment for high blood pressure and cholesterol, sufficient physical activity[197], smoking status, lifetime risk of harm to health from alcohol consumption[198], and overweight or obese status[152] (as determined by the body mass index (BMI) (self-reported weight in kilograms divided by height in meters squared) ≥ 25.0). Recommended amounts of fruit and vegetables for people aged 18 years or more were defined as having at least 5 daily servings of vegetables and 2 daily servings of fruit[199]. Recommended daily servings of fruit (1–2 servings) and vegetables (2.5–5.5 servings) for children aged 2–17 years varied according to age[199].

Food insecurity was defined as households running out of food or could not afford to buy more in the last 12 months. Respondents were asked the number of times they had takeaway (carryout) food per week. The family money situation was divided into 2 groups: unable to save (spending more money than getting, having just enough to get through to the next pay, having some money left over each week but just spending it) and able to save (can save a bit occasionally or a lot).

5.4.5   Survey weight adjustment methods

Raking is an iterative process, and usually 1 variable at a time is applied to the proportional adjustment of the weights. The data are gradually adjusted to fit to specific characteristics so the survey variables (or survey margin totals) match with population variables (or control totals) such as census data[134, 190, 200]. The iterative process is finalized when the differences between all the categories' proportions from the census data and raked weights from the survey data margin are convergent within an acceptable predefined tolerance limit of 0.025[190, 201]. For example, the raked weighted proportion of males from the survey data (49.3%) is the same as the census proportion of males (49.3%). Alternatively, the process is terminated once a predefined set number of iterations has been reached, for example, 60[190]. As recommended by Izrael et al[190] and Battaglia et al[200, 202], raked weights that had extremely high or low weight values in our sample were trimmed to reduce their impact on the variance of the estimates by recoding weights larger or smaller than the median weight plus 6 times the interquartile range of the weight to these limits. A raking program, using SPSS version 20.0 syntax code (IBM SPSS Statistics for Windows software; IBM Corp., Armonk, New York), to calculate the raked weights was developed, and the base design weight (the number of people living in the household and the number of telephone listings in the telephone directory) was included in the calculation. User-written programs on raked weights have been developed and are available for general use in SPSS (*SPSS_RAKE*) and Stata (*ipfraking*) statistical software (StataCorp LP, College Station, Texas).

Poststratification weighting of SAMSS used area of residence (metropolitan Adelaide, Rural or remote areas), 10-year age groups, sex, and probability of selection in the household to the most recent estimated residential population or census data. Probability of selection in the household is based on the number of people living in the household and the number of telephone listings in the telephone directory.

A detailed explanation of poststratification and raked weights is in Section 5.7.

5.4.6 Statistical analyses

Data analysis was conducted by using SPSS version 20.0. Prevalence estimates were presented for self-reported fair or poor health, diabetes, current smokers, and current high blood pressure by using poststratification weights and raked weights. These 4 variables were used to demonstrate the impact on the estimates by use of different sociodemographic variables, besides age, sex, and area of residence, in raked weights. For other selected health indicators, the differences between poststratification weights and the fully raked weights were calculated. The raked-weight methodology was assessed by comparing the raked estimates with 2 external data sources: the 2013 Health Omnibus Survey (HOS) [149] and the 2011–2012 Australian Health Survey (AHS) [203] where the questions were the same or very similar. HOS is an annual face-to-face household survey of South Australians with a 57.6% response rate, and the AHS is a face-to-face survey of all Australians with an 85.9% response rate. Both of these surveys use poststratification methods to calculate their survey weights and include mobile-only households in their sampling frame.

5.5 Results

When compared with census estimates, the unweighted age distribution of SAMSS had a higher proportion of older people and a lower proportion of younger people, as well as a higher proportion of females (Table 5.2). SAMSS had a lower proportion of people who rent, were employed, or were unemployed and a higher proportion who were born in Australia or the United Kingdom, married or living with a partner, and economically inactive. Poststratification weighting reduced the differences for dwelling status, employment status, and marital status.

Table 5.3 demonstrates the effect on the prevalence estimates for fair or poor health, diabetes, current smokers, and current high blood pressure of including the 9 variables, cumulatively, in the raked weights. All 4 of the prevalence estimates changed, as expected, when the typical age, sex, and area of residence variables were included in the raked and poststratification weights. When the other sociodemographics were added, individually or as a whole, the prevalence of diabetes and current high blood pressure changed slightly. The prevalence of self-reported fair or poor health increased when dwelling status (rent vs. other) and number of people in the household were included in the raked weights, and it increased by almost 3% with all 9 variables included in the raked weights. This pattern was similar for prevalence of current smokers, where the prevalence estimate increased by almost 2% with the addition of dwelling status and number of people in the household and a further 2% when all 9 variables were applied in the raked weights.

Table 5.4 shows the differences and percentage differences in the prevalence estimates between poststratification and fully raked weights on a range of selected health conditions, behavioral health risk factors, and socioeconomic conditions. More than half of the variables showed minimal differences in their prevalence when fully raked weights were applied compared with using the poststratification weight.

Table 5.5 shows the estimates from SAMSS using both poststratified and raked weights and the estimates from the face-to-face surveys. Little difference is seen in the estimates for current asthma (SAMSS and HOS) and sufficient daily consumption of vegetables (SAMSS and AHS). The raked-weight estimates for diabetes, arthritis, psychological distress, current smokers, and undertaking sufficient physical activity are similar to the estimates from HOS and AHS, in contrast to the poststratification estimates. The poststratification weight estimates for self-reported fair or poor health, overweight and obesity, and sufficient daily consumption of fruit are closer to the estimates from HOS and AHS compared with the raked estimates.

Table 5.2: Demographic profile of the South Australian 2011 Census and estimates for all age groups from the 2013 South Australian Monitoring and Surveillance System using unweighted data and data with poststratified weights and fully raked weights

Sociodemographic Variable	2011 Census (n = 1.60 million), %	Unweighted %	% Difference[c]	Poststratification Weights[a] %	% Difference[c]	Fully Raked Weights[b] %	% Difference[c]
Age groups, years							
0–9	11.9	7.2	−4.70	11.9	0.00	11.9	0.00
10–15	7.4	5.7	−1.70	7.4	0.00	7.4	0.00
16–34	24.4	10.5	−13.90	24.4	0.00	24.4	0.00
35–44	13.5	5.9	−7.70	13.5	0.00	13.6	0.00
45–54	14.1	12.2	−1.89	14.1	0.00	14.1	0.00
55–64	12.5	20.1	7.65	12.5	0.00	12.5	0.00
65–74	8.3	21.4	13.05	8.3	0.00	8.3	0.00
75	7.8	17.0	9.21	7.8	0.00	7.8	0.00
Sex							
Male	49.3	42.1	−7.17	49.3	0.00	49.3	0.00
Female	50.7	57.9	7.17	50.7	0.00	50.7	0.00
Area of residence							
Metropolitan Adelaide	71.6	63.7	−7.92	71.6	0.00	71.6	0.00
Rural or remote areas	28.4	36.3	7.92	28.4	0.00	28.4	0.00
Dwelling status							
Owned or being purchased, other	72.2	86.5	14.24	85.4	13.16	72.2	0.01
Rent	27.8	13.5	−14.24	14.6	−13.16	27.8	−0.01
Country of birth							
Australia	76.9	78.7	1.79	82.9	5.99	76.9	0.00
United Kingdom	8.3	11.5	3.21	7.5	−0.76	8.3	0.00
Europe	5.4	5.6	0.22	4.1	−1.26	5.4	0.00
Other	9.5	4.2	−5.22	5.5	−3.96	9.5	0.00

Note: SAMSS, South Australian Monitoring and Surveillance System. a Three variables included in poststratification weights (age, sex, area of residence). b All 9 variables included in raked weights (age, sex, area of residence, dwelling status, country of birth, marital status, educational level, employment status, and number of people in household). c Percentage differences are between the 2011 Census and SAMSS.

Table 5.2: Demographic profile of the South Australian 2011 Census and estimates for all age groups from the 2013 South Australian Monitoring and Surveillance System using unweighted data and data with poststratified weights and fully raked weights

| | 2011 Census | | | 2013 SAMSS (*n* = 7,193) | | | |
| | (*n* = 1.60 | Unweighted | | Poststratification Weights[a] | | Fully Raked Weights[b] | |
Sociodemographic Variable	million), %	%	% Difference[c]	%	% Difference[c]	%	% Difference[c]
Marital status							
Married/living with partner	43.2	49.8	6.62	47.7	4.52	43.1	−0.04
Other	37.6	37.3	−0.26	33.0	−4.56	37.6	0.00
Under 16 years	19.2	12.9	−6.36	19.3	0.03	19.3	0.04
Educational level							
None to some high school, trade, certificate, diploma	69.8	70.8	1.01	63.9	−5.90	69.8	−0.03
Degree or higher	11.0	16.3	5.35	16.8	5.86	11.0	−0.01
Under 16 years	19.2	12.9	−6.36	19.3	0.03	19.3	0.04
Employment status							
Full-time employed	31.2	21.4	−9.74	28.1	−3.04	31.2	0.01
Part-time employed	17.1	14.4	−2.73	16.1	−0.96	17.1	0.01
Unemployed	2.9	1.5	−1.39	1.9	−0.96	2.8	−0.09
Economically inactive (home duties, student, retired, unable to work because of illness)	29.6	49.9	20.22	34.6	4.93	29.7	0.02
Under 16 years	19.2	12.9	−6.36	19.3	0.03	19.3	0.04
No. of people in the household (including children)							
1	26.4	25.9	−0.49	9.4	−17.07	26.4	−0.04
2	34.7	41.1	6.43	27.7	−6.97	34.7	−0.01
3	15.5	12.2	−3.31	18.0	2.50	15.6	0.02
4	23.4	20.7	−2.62	44.9	21.55	23.4	0.03

Note: SAMSS, South Australian Monitoring and Surveillance System. a Three variables included in poststratification weights (age, sex, area of residence). b All 9 variables included in raked weights (age, sex, area of residence, dwelling status, country of birth, marital status, educational level, employment status, and number of people in household). c Percentage differences are between the 2011 Census and SAMSS.

Table 5.3: Effect of including different sociodemographic variables in the raked weights on health prevalence estimates for persons aged 16 years or more, South Australian Monitoring and Surveillance System, 2013

Variables Used in Poststratified and Raked Weights	Fair/poor overall health		Diabetes		Current smokers		Current high blood pressure	
	%[a]	95% CI	%	95% CI	%	95% CI	%	95% CI
Unweighted	20.3	(19.3 - 21.3)	12.0	(11.3 - 12.9)	11.5	(10.8 - 12.4)	34.9	(33.7 - 36.0)
Poststratification weight	15.3	(14.4 - 16.3)	7.7	(7.1 - 8.4)	12.8	(11.9 - 13.6)	20.7	(19.6 - 21.7)
Raked weights calculated by using								
Age, sex, area of residence	15.5	(14.5 - 16.4)	7.6	(7.0 - 8.3)	12.7	(11.9 - 13.6)	20.7	(19.6 - 21.7)
Age, sex, area of residence, dwelling status	16.5	(15.6 - 17.5)	8.1	(7.4 - 8.8)	14.4	(13.5 - 15.3)	21.0	(20.0 - 22.1)
Age, sex, area of residence, country of birth	15.4	(14.4 - 16.3)	7.7	(7.0 - 8.4)	12.5	(11.7 - 13.4)	20.6	(19.6 - 21.7)
Age, sex, area of residence, marital status	15.9	(14.9 - 16.8)	7.7	(7.1 - 8.5)	13.3	(12.4 - 14.2)	20.8	(19.8 - 21.9)
Age, sex, area of residence, educational attainment	15.8	(14.8 - 16.7)	7.8	(7.2 - 8.6)	13.6	(12.7 - 14.5)	21.2	(20.1 - 22.2)
Age, sex, area of residence, employment status	14.8	(13.9 - 15.8)	7.5	(6.8 - 8.2)	12.9	(12.1 - 13.8)	20.3	(19.3 - 21.3)
Age, sex, area of residence, no. of people in household	16.7	(15.7 - 17.6)	8.2	(7.5 - 8.9)	14.7	(13.8 - 15.6)	21.2	(20.2 - 22.3)
Age, sex, area of residence, dwelling status, country of birth	16.4	(15.4 - 17.3)	8.1	(7.4 - 8.8)	14.2	(13.3 - 15.1)	21.1	(20.1 - 22.2)
Age, sex, area of residence, dwelling status, country of birth, marital status	16.7	(15.7 - 17.6)	8.2	(7.5 - 8.9)	14.7	(13.8 - 15.6)	21.2	(20.2 - 22.3)
Age, sex, area of residence, dwelling status, country of birth, marital status, educational attainment	17.1	(16.2 - 18.1)	8.3	(7.6 - 9.0)	15.5	(14.6 - 16.5)	21.8	(20.7 - 22.9)
Age, sex, area of residence, dwelling status, country of birth, marital status, educational attainment, employment status	16.0	(15.1 - 17.0)	8.0	(7.3 - 8.7)	15.6	(14.7 - 16.6)	21.3	(20.2 - 22.3)
Fully raked (9 variables): age, sex, area of residence, dwelling status, country of birth, marital status, educational level, employment status, no. of people in household	18.1	(17.1 - 19.1)	8.4	(7.8 - 9.2)	16.3	(15.4 - 17.3)	21.6	(20.6 - 22.7)

Abbreviation: CI, confidence interval.

a All prevalence values are estimates.

Table 5.4: Prevalence estimates, differences, and percentage change of various health conditions, behavioural health risk factors, and other health-related issues between poststratified weights and raked weights, South Australian Monitoring and Surveillance System, 2013

Variable	Poststratification Weights		Fully Raked Weights		Differences, %	% Change
	%[a]	95% CI	%[a]	95% CI		
Health conditions						
Current asthma (children)	13.8	(12.0 - 15.8)	14.1	(12.3 - 16.2)	0.3	2.2
At least 1 chronic condition	38.3	(37.1 - 39.6)	40.3	(39.0 - 41.6)	2.0	5.2
Cardiovascular disease	7.4	(6.8 - 8.1)	7.8	(7.2 - 8.6)	0.4	5.4
Current asthma (adults)	13.2	(12.3 - 14.1)	14.0	(13.1 - 14.9)	0.8	6.1
Osteoporosis	4.4	(3.9 - 5.0)	4.7	(4.2 - 5.3)	0.3	6.8
Chronic obstructive pulmonary disease	3.4	(3.0 - 3.9)	3.7	(3.3 - 4.3)	0.3	8.8
Diabetes	7.7	(7.1 - 8.4)	8.4	(7.8 - 9.2)	0.7	9.1
Arthritis	20.6	(19.5 - 21.6)	23.0	(22.0 - 24.1)	2.4	11.7
Self-reported fair or poor	15.3	(14.4 - 16.3)	18.1	(17.1 - 19.1)	2.8	18.3
Current diagnosed mental health condition	16.6	(15.7 - 17.6)	20.0	(19.0 - 21.1)	3.4	20.5
Psychological distress (Kessler 10)	8.8	(8.1 - 9.6)	11.3	(10.5 - 12.1)	2.5	28.4
Suicidal ideation	3.6	(3.1 - 4.1)	5.1	(4.6 - 5.7)	1.5	41.7
Behavioural health risk factors						
Sufficient servings of fruit per day (children)	67.1	(64.8 - 69.3)	67.8	(65.3 - 70.2)	0.7	1.0
Lifetime risk of harm due to alcohol consumption	33.1	(31.9 - 34.3)	32.7	(31.5 - 33.9)	−0.4	−1.2
Sufficient physical activity	42.7	(41.4 - 44.0)	40.9	(39.7 - 42.2)	−1.8	−4.2
Overweight/obesity	59.0	(57.6 - 60.3)	61.5	(60.2 - 62.8)	2.5	4.2

Abbreviation: CI, confidence interval.

a All prevalence values are estimates.

Table 5.4: Prevalence estimates, differences, and percentage change of various health conditions, behavioural health risk factors, and other health-related issues between poststratified weights and raked weights, South Australian Monitoring and Surveillance System, 2013

Variable	Poststratification Weights		Fully Raked Weights		Differences, %	% Change
	%[a]	95% CI	%[a]	95% CI		
Sufficient servings of fruit per day (adults)	44.3	(43.0 - 45.6)	42.4	(41.1 - 43.7)	−1.9	−4.3
Current high blood pressure	20.7	(19.6 - 21.7)	21.6	(20.6 - 22.7)	0.9	4.3
Current high cholesterol	16.9	(16.0 - 17.9)	17.7	(16.8 - 18.7)	0.8	4.7
Sufficient servings of vegetables per day (adults)	11.7	(10.9 - 12.6)	11.1	(10.3 - 11.9)	−0.6	−5.1
Having at least 1 day off from usual activities due to health	13.7	(12.1 - 15.4)	14.5	(12.7 - 16.4)	0.8	5.8
Sufficient servings of vegetables per day (children)	14.1	(13.2 - 15.0)	16.5	(15.6 - 17.5)	2.4	17.0
Current smoker	12.8	(11.9 - 13.6)	16.3	(15.4 - 17.3)	3.5	27.3
Having takeaway (carryout) 3 or more times per week	1.9	(1.6 - 2.3)	2.5	(2.2 - 2.9)	0.6	31.6
Smoking in home occasionally or all the time	4.7	(4.0 - 5.4)	6.5	(5.7 - 7.3)	1.8	38.3
Food supply insecure	3.2	(2.8 - 3.7)	6.1	(5.6 - 6.7)	2.9	90.6
Other health-related issues (financial situation, unable to save)	28.2	(27.1 - 29.2)	31.6	(30.5 - 32.7)	3.4	12.1

Abbreviation: CI, confidence interval.

a All prevalence values are estimates.

Table 5.5: Comparison of prevalence estimates from poststratified and raked weights with face-to-face surveys, Australia, 2011–2013

	South Australian Monitoring and Surveillance System, 2013		South Australia Health Omnibus Survey, 2013 (*n* ~3,000) [149]	Australian Health Survey, 2011–2012 (South Australia Results Only) (n = 2,508) [203]
	Poststratified Weights (%)	Fully Raked Weights (%)		
Fair or poor health (self-rated)	15.4	18.1		14.7
Diabetes	7.7	8.4	8.5	
Osteoporosis	4.5	4.7	6.0	
Arthritis	20.6	23.0	22.0	
Current asthma [a]	12.0	12.9	12.7 b	
Psychological distress (Kessler 10)	8.8	11.3		11.4
Body mass index				
Overweight and obese	58.9	61.5	58.6	
Normal	38.6	36.3	39.5	
Missing data	6.1	6.1	9.4	
Current smokers	12.7	16.3	16.7 c	16.6
Sufficient physical activity [d]	41.6	40.4	39.7	
Sufficient daily consumption of fruit [f]	44.2	42.4		46.1
Sufficient daily consumption of vegetables [d]	11.7	11.1		10.0

a Have you ever been told by a doctor that you have asthma? Do you still have asthma?
b 2011 Health Omnibus Survey estimates.
c 2012 Health Omnibus Survey estimates.
d Persons aged 18 years or more.

5.6 Discussion

This study highlights that using the statistical weighting formula, raked weights can improve health and behavioral risk factor estimates by incorporating a range of sociodemographic variables to overcome bias in telephone surveys. With declining response rates and inadequate sampling frames, specific groups of the community (e.g., people who rent) are often under-represented in telephone surveys that can result in an under- or over-estimation of the prevalence of health indicators. These findings imply that, for some health estimates, the limited sociodemographics incorporated in poststratification weighting methods (age groups, sex, and area of residence) are not sufficient to reduce bias in health estimates of the general population. By incorporating the

6 additional sociodemographic variables in the raked weighting formula into surveillance data, this study has demonstrated that the estimates are more in line with the more expensive national and state-based face-to-face surveys. The raked-weighting methodology has made it relatively easy to add many sociodemographic variables, which was not possible with the traditional poststratification weighting methods.

To our knowledge, this study is the first of its kind in the Australian context. It is unique in having a large sample, so that the conclusions are likely to be generalisable to the Australian population and are also applicable internationally, given that many of the issues regarding bias in telephone surveys are similar[62, 142]. Most international studies of this kind are from the United States using BRFSS data[15, 204-208]. Our study used sociodemographic variables in the raked weights similar to those of BRFSS [209] with but a few minor differences. Our study used country of birthplace instead of race because race is not commonly used or collected in Australian health surveys. Similar findings included the following: minimal prevalence differences in diabetes, cardiovascular diseases (heart attack, stroke), and current asthma[204-207] (<1% differences) and large differences in prevalence estimates (1%–3%) for overweight and obesity, fair or poor health, and physical activity. The difference between current smoking estimates in our study was 3.6%, which is less than the differences of 6%–7% reported in the BRFSS[15, 204-207].

Comparing the raked health estimates with two face-to-face surveys (both include mobile-only households that are excluded from telephone surveys and used poststratification weights) produced mostly similar but some mixed results. Similar estimates were found for arthritis, psychological distress, current smokers, diabetes, vegetable consumption, and sufficient levels of physical activity. The prevalence of sufficient servings of fruit suggests that using raked weights (42.4%) moved away from the AHS estimate (46.1%). The higher prevalence in the AHS compared with the SAMSS, even though the questions were the same, could be explained by the additional interviewer prompt in the AHS and the inclusion of tomatoes in the definition of fruit[210].

Similarly, the raked weighted estimates for overweight and obesity (61.5%) were different from poststratification weights (58.9%) compared with HOS (58.6%). A possible explanation could be the larger proportion missing data from HOS (9.4%) compared with SAMSS (6.1%). The raked weighted estimate for fair or poor health (18.1%) was higher than the AHS estimate (14.7%). This difference could be attributable to mode effect; that is, people tend to report more socially desirable responses on the basis of survey mode. It has been suggested that, for nonfactual questions such as self-rated health or quality-of-life type questions, the physical presence of an interviewer can cause the respondent to give a more positive rating of their health[211].

Although some of the estimates examined in this study did not change when raked weights were applied, there were large changes in the estimates occurring among health indictors that were strongly related to groups under-represented in telephone surveys because of non-coverage (exclusion of mobile-only households) and nonresponse, such as people who rent and young people (Table 5.1). Previous studies have shown that health estimates, with higher prevalence among socioeconomically disadvantaged households or younger people, can be under-estimated in telephone surveys because of nonresponse bias (non-coverage and lower response rates)[107, 146]. This is shown in our study where substantial changes occurred in the health estimates for food insecurity, mental health conditions, fair or poor health, overweight and obesity, and not sufficiently active. These estimates changed considerably with the addition of dwelling status (rent vs.other) in the raked weights (Table 5.4). This suggests the raked weights better adjust these estimates by eliminating some of the bias due to nonresponse and sampling coverage problems. However, if the current trends of mobile-only households continue to increase[109], then other efficient sampling strategies for chronic disease and surveillance systems may need further investigation to include the sociodemographic groups that are under-represented in telephone surveys. As it stands, the current suggested methodologies for use in Australia that include mobile-only households in the sample frame[103, 116] are not feasible or sustainable and are too costly for use in SAMSS and similar systems.

The study design is robust because of the large, representative, statewide samples used and the large range of health conditions and health-related risk factors assessed. The raked-weighting methodology reliant on data from the census, which is conducted every 5 years, can be seen as a limitation. However, further analysis revealed minimal changes between the 2006 Census and the 2011 Census. Another limitation is that some sociodemographic variables or categories, which were considered important, could not be included because of insufficient sample size, such as Aboriginal and/or Torres Strait Islander status. Other limitations occurred when the question or categories were not comparable between SAMSS and the census, such as never married, separated, or divorced, or when the proportion of missing data was too high, such as for household income. It should also be noted that use of the census as the benchmark could also be introducing additional biases because of respondent error, processing error, partial or nonresponse, and undercount since the census is a self-completed survey. About 3.7% of the census forms were not returned from a private dwelling in 2011, and the count data were imputed on the basis of similar dwellings in the surrounding area. Variable item nonresponse for South Australia ranged from 0.9% to 14.2% with a median rate of 4.5%, and the variables that had high nonresponse were residential status in a nonprivate dwelling, that is, communal type of accommodations (14.2%) (not used in this study), and the highest year of school completed (7.5%) (used with other training and education variables). Given that around 5% of the census data items used in the raking methodology are imputed, we are confident that the estimates would be slightly biased.

The use of a raking weighting methodology has overcome, to some extent, the nonresponse bias associated with the sampling methodology of telephone surveys. Raking methodology has the advantage over poststratification methods for surveillance data from a relatively small sample size and the option to incorporate more sociodemographic variables. Our results suggest that raking methodology for telephone surveys requires additional sociodemographic variables besides the usual age, sex, and area that were

previously used and that the estimates correspond well with those from face-to-face surveys. Surveillance systems are always evolving to accommodate technological and societal changes. Implementing raked weights in surveillance systems will change the prevalence of some estimates and will cause breaks in trend data. Therefore, strategies are needed to educated users on the changes in methodology to avoid misinterpretation of the findings.

5.7   Appendix

5.7.1   Raked weight adjustment methods

The raking steps are as follows:

Set weight = design weight.

Repeat the following steps until reached tolerance level for all margins or the number of iterations = 60.

For each v margin variable

Calculate weighted sample total = sum(weight);

Calculate weighted totals for each category in variable v = sum(weight$_{v\text{ categories}}$);

Weight = weight × % population$_{v\text{ categories}}$ / [sum(weight$_{v\text{ categories}}$)/sum(weight)];

End

Trim weights;

Rescale weight if weighted sample total is not equal to total unweighted sample size;

End

By use of the following notations where n is the total sample size; N is the total population size (census); v denotes variable; u denotes category; k is the number of variables; j is the number of categories within variable v; T_v is the population proportion (control totals) calculated for each category, j, in

variable, v; i is the individual in the sample, n; m is the number of iterations; and $w_i^{(m,v)}$ is the weighting variable for individual i at iteration m and variable, v, the raked weights are calculated as follows:

Initialise;

> $T_v = N_{v,u}/N_v$, calculate the population control totals for each $v = 1, ..., k$ variables each with $u = 1, ..., j$ categories;

> $m = 0$, initialise iteration variable;

> $w_i^{(0,0)}$ = design weight, set the weight variable to the sample design weight

For iteration 1, $m = 1$, do the following for each v margin variable ($v = 1, ..., k$):

> Do the following for each u categories ($u = 1, ..., j$):

$$w_i^{(1,k)} = w_i^{(1,k-1)} \times T_k \times \left(\frac{\sum w_{i,k,u}^{(1,k-1)}}{\sum w_{i,k}^{(1,k-1)}} \right).$$

Reiterate the above calculations until the tolerance level has been reached for all k margins (i.e., $T_k - (\sum w_{i,k,u}^{(m,k)}/\sum w_{i,k}^{(m,k)}) < 0.025$; or the number of iterations, m, has been reached such as 60:

For iteration, m, do the following, where $v = 1, ..., k$

> Do the following for each u category ($u = 1, ..., j$):

$$w_i^{(m,k)} = w_i^{(m,k-1)} \times T_k \times \left(\frac{\sum w_{i,k,u}^{(m,k-1)}}{\sum w_{i,k}^{(m,k-1)}} \right).$$

5.7.2 Poststratification weight adjustment methods

The traditional poststratification weighting (or cell weighting) applied for each individual (which includes the design weight in the formula), each month is

$$w_{h,i} = d_{h,i} \times \frac{N_h}{\sum_{i=1}^{n_h} d_{h,i}} \times \frac{n}{N},$$

where N is the total population size; n is the total sample size; h is the stratum, age groups × sex × area of residence; N_h is the population size of stratum h; n_h is the sample size in stratum h; $w_{h,i}$ is the weighting value for respondent i in stratum h; and $d_{h,i}$ is the household size for respondent i in stratum h.

Chapter 6: Publication - Pre-survey text messages (SMS) improve participation rate in an Australian mobile telephone survey: an experimental study

6.1 Statement of Authorship

Title of Paper	Pre-survey text messages (SMS) improve participation rate in an Australian mobile telephone survey: an experimental study.
Publication Status	☑ Published ☐ Accepted for Publication ☐ Submitted for Publication ☐ Unpublished and Unsubmitted work written in manuscript style
Publication Details	PlosOne, 2016; 11(2): e0150231 DOI: 10.1371/journal.pone.0150231

Name of Principal Author (Candidate)	Eleonora Dal Grande		
Contribution to the Paper	Participated in the design and co-ordination of the study, performed statistical analyses, and drafted and revised the manuscript.		
Overall percentage (%)	85%		
Certification:	This paper reports on original research I conducted during the period of my Higher Degree by Research candidature and is not subject to any obligations or contractual agreements with a third party that would constrain its inclusion in this thesis. I am the primary author of this paper.		
Signature		Date	15/6/2016

Name of Co-Author	Catherine R. Chittleborough		
Contribution to the Paper	Provided advice on the analyses, and was involved in the drafting and revising of the manuscript. I give permission for Eleonora Dal Grande to present this paper for examination towards the doctor of Philosophy.		
Signature		Date	6/6/2016

Name of Co-Author	Stefano Campostrini		
Contribution to the Paper	Provided advice on the analyses, and was involved in the drafting and revising of the manuscript. I give permission for Eleonora Dal Grande to present this paper for examination towards the doctor of Philosophy.		
Signature		Date	10/6/2016

Name of Co-Author	Maureen Dollard		
Contribution to the Paper	Participated in the design and co-ordination of the study, and revising of the manuscript. I give permission for Eleonora Dal Grande to present this paper for examination towards the doctor of Philosophy.		
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Name of Co-Author	Anne W. Taylor		
Contribution to the Paper	Participated in the design and co-ordination of the study, advice on the analyses, and was involved in the drafting and revising of the manuscript. I give permission for Eleonora Dal Grande to present this paper for examination towards the doctor of Philosophy.		
Signature		Date	15/6/2016

6.2 Abstract

Mobile telephone numbers are increasingly being included in household surveys samples. As approach letters cannot be sent because many do not have address details, alternatives approaches have been considered. This study assesses the effectiveness of sending a short message service (SMS) to a random sample of mobile telephone numbers to increase response rates. A simple random sample of 9000 Australian mobile telephone numbers: 4500 were randomly assigned to be sent a pre-notification SMS, and the remaining 4500 did not have a SMS sent. Adults aged 18 years and over, and currently in paid employment, were eligible to participate. American Association for Public Opinion Research formulas were used to calculated response cooperation and refusal rates. Response and cooperation rate were higher for the SMS groups (12.4% and 28.6% respectively) than the group with no SMS (7.7% and 16.0%). Refusal rates were lower for the SMS group (27.3%) than the group with no SMS (35.9%). When asked, 85.8% of the pre-notification group indicated they remembered receiving a SMS about the study. Sending a pre-notification SMS is effective in improving participation in population-based surveys. Response rates were increased by 60% and cooperation rates by 79%.

6.3 Background

Many chronic disease and risk factor surveillance systems in Australia use the telephone as an efficient way to collect information. The telecommunication industry has undergone many changes over the last 15 years which has had an impact on traditional landline-based surveys. Increased non-coverage and declining participation has required telephone survey researchers to adjust their methodology[17, 62]. There has been an increase in mobile-only households in Australia and internationally[107, 146, 148], and this has had an impact on the coverage of landline-based surveys[62, 160]. As a result many systems are incorporating mobile telephone samples into their surveys resulting in dual-frame sampling methods[15, 62, 106, 108].

Incorporating mobile telephones samples into population surveys has brought challenges in both sampling and participation[129, 212]. In Australia, there is the difficulty in obtaining a representative sampling frame of mobile telephone numbers since they are rarely listed (7.3% of mobile telephone owners in South Australia are listed)[213]. Several studies in Australia used a random-digit dial (RDD) list of mobile telephone numbers[103, 116] but this is compromised as mobile telephone numbers do not include address details or geographical location. As such, sending a primary approach letter (PAL) is not possible for geographically restricted surveys. Landline telephone numbers from directory-listed sampling frames that include address details allow the option of sending a PAL, which softens the impact of unsolicited calls and has been shown to improve response rates[122].

There are a number of factors which have influenced people's participation in surveys using mobile telephones. The function of caller ID has contributed to this decline in response rates due to privacy concerns, survey burden and has enable the user to screen calls[87]. People are worried about the invasion of their privacy and have developed a mistrust of unsolicited calls[86]. A United States (US) study indicated that only 44% of people would let the call go to voice mail, 10% would ignore the call all together and 44% will answer the call[214]. The different 'user culture' associated with mobile telephones includes people

regarding their mobiles as a private tool when compared to landline telephones with mobile telephones predominately used to converse with close friends and family members[155]. This makes it increasingly difficult to make 'cold' calls to mobile telephones[215]. Another challenge is the location at the time of data collection with landline interviews undertaken within the respondent's home while mobile interviews can additionally be undertaken in a wide range of environments outside the home. This means interviews via mobile telephones increases cognitive burden, therefore providing additional distractions, and challenges privacy considerations which can lead to higher breakoff or refusal to participate[216, 217]. Unlike landline telephones, mobile telephones have various platforms: different operating systems, features, screen sizes, touch screens, keyboard or keypad options, different modes or formats of text messaging; all which have an impact on the way people interact or use their mobile telephones[129]. These issues are associated with lower response rates for mobile telephone interviews compared to landline telephone surveys resulting in the need for alternative methods to increase response rates.

A standard feature of mobile telephones is the ability to communicate by Short Message Service (SMS) or, more commonly known as, text messaging. In Australia, 85% of adults owning a mobile telephone indicated that they use SMS[218]. It is a relatively cheap way of communicating with a higher proportion of young people opting to SMS rather than call[219]. SMS has been used for many years in businesses as a reminder to clients of their appointment time and date[220]. This indicates the potential to incorporate SMS into survey methodology and improve response rates, especially among the difficult to reach groups such as the young and highly mobile people. Unlike PAL, SMS is considered fast, is received immediately or stored until the message is able to be read, and there is an immediate notification of a non-working number. With current available technology, SMS can be sent simultaneously to a large number of people.

Few studies have tested the effectiveness of sending pre-notification SMS to increase participation in population-based mobile telephone surveys. These

previous studies indicated that there are no differences in the response rates for those who were sent a pre-notification SMS compared to those who were not[215, 216, 221, 222]. Although the response rate was not different, Steeh et al[215] found that surveys incorporating a pre-notification SMS had an increased cooperation rate (50.1% compared to 41.5%), lower refusal rate (10.3% compared to 21.1%) and fewer call attempts compared to no SMS. In a study conducted by DuBray,[221] only a third of the respondents indicated they recalled receiving a pre-notification SMS (33%) which could explain the lack of observed difference in response rate. It should be noted that these studies were conducted in the US where the receiver of the incoming SMS pays for the incoming call[155, 215]. However, the payment system in Australia and Europe is different, with cost of the SMS paid by the person or organisation sending the SMS.

The current study was designed to examine the role of SMS in increasing response rates in Australia. This study was part of a broader project which included current workers[223]. Previous data collection for the project was solely based on a directory-listed landline sampling frame. Literature indicated that the proportion of currently employed adults had higher rates of mobile-only households, and limiting the sample to a directory-listed landline sampling frame would result in a lower proportion of young people, people living in lower socioeconomic status (SES) areas, and renters[107, 146]. Thus, a dual-frame telephone sampling approach was considered. This involved two different telephone sampling frames: a landline telephone sample and a mobile telephone sample.

The aim of this study was to test if sending pre-notification SMS to inform users of an imminent mobile telephone call from researchers about a survey improves response rates and participation in a population-based study among mobile telephone users. Because the uptake and saturation of mobile telephones has grown so quickly since the mid2000s[107, 146], and the technology has changed and evolved over the last decade as well as people's behaviours[19], the literature in this area is sparse and, moreover, findings from five years ago may not be relevant or applicable today.

6.4 Methods

6.4.1 Survey design and sample selection

This study is part of the Australian Workplace Barometer (AWB) project which aims to provide epidemiological evidence of Australian workplace conditions[223]. For this paper, only the methodology for the mobile telephone study will be presented. The sample frame used a randomly generated mobile telephone number supplied by Sampleworx[213]. Since the sample had no geographical marker, the sample could not be stratified by state or territory, hence, the mobile telephone sample was a random selection of mobile numbers of Australia.

Ethical approvals were obtained from the Research Ethics Committees of The University of Adelaide and the University of South Australia at each stage of the AWB project including this study to test sending a pre-notification text. Participation in the study is voluntary. Verbal informed consent was obtained from participants at the start of the interview and confirmation to continue participation in the telephone interview was obtained and recorded as yes or refusal within the questionnaire. The study was conducted via the mobile telephone and obtaining written consent or sending a primary approach letter (PAL) was not feasible due to inability and unwillingness of respondents to provide mailing address details. Upon initial contact, respondents can have a PAL mailed out if requested. Consent was recorded as a complete interview and reasons for non-participation or unable to establish contact were also recorded.

A simple random sample of 9000 mobile telephone numbers Australia- wide was selected. To determine the effectiveness of sending a pre-notification SMS, 4500 mobile numbers were randomly selected to be sent a SMS. To be eligible to for participation had to be interviewed, respondents had to be an adult aged 18 years and over, and currently in paid employment. We assumed that the person who answered the mobile telephone was the primary user. People who were self-employed were not eligible to participate. There were no

replacements for non-contactable persons. Data collection for this study occurred between 29 October 2014 and 23 February 2015. All interviews were conducted in English.

6.4.2 SMS messages

SMS messages were sent using smsglobal (www.smsglobal.com), a web messaging platform (MXT), which is a management tool to send SMS online. The MXT has options to send from a dedicated number or from words limited to 11 characters. We chose to have "Uni SA AWB" since the University of South Australia is a well-known and respected institution, and the results from an internet search using these terms provides links to AWB material. The length of the message was set at the standard 160 characters (including spaces). The 160 characters was costed as one SMS message; any more would have doubled the cost. The main aim of the message was to inform the participant that they were going to receive a call, the number that was going to be used and a free-call 1800 number to call if they had any queries. The respondents did not have the option to reply by sending a SMS. Random batches of mobile numbers were selected daily and scheduled for SMS to be sent at noon each day with the telephone call made later that evening. Smsglobal software flags SMS messages that were unsuccessfully sent, indicating that the mobile telephone number was not active and could be removed from the sample. As part of the market and social research industry standards in Australia, both sample groups had the telephone number of the caller appearing on the screen, in this case, a landline telephone number. No other information, such as "UNI SA AWB" appeared when calling to the mobile telephone. Up to three SMS were sent to the participants to obtain an interview. The follow-up SMS messages were worded almost the same as the initial SMS (see Section 6.7). For both sample groups, if there was no answer, the interviewer left a voice message if possible (see Section 6.7). Up to five call-backs were made to establish contact.

6.4.3 Sociodemographics

Sociodemographic variables included in these analyses were age group, sex, country of birth (Australia, outside Australia), educational attainment (bachelor degree level or higher, below bachelor level), and working hours (full time, part time).

6.4.4 Statistical analyses

The response rate was used to determine the effectiveness of pre-notification SMS. The final dispositions of the mobile telephone numbers were classified using the American Association for Public Opinion Research (AAPOR) standard definitions[75]. A series of outcome rates[75] were calculated to evaluate the performance between the SMS and no SMS mobile telephone groups. There are different formulas for each rate to incorporate the unknown eligibilities of some mobile telephones:

- response rates (RR): The number of complete interviews divided by the number of eligible respondents in the sample.
- cooperation rates (COOP): The number of all cases interviewed divided by all eligible respondents ever contacted.
- refusal rates (REF): The number of all respondents who refused to be interviewed, or terminated an interview, divided by all potentially eligible cases.
- contact rates (CON): The proportion of all cases in which some responsible housing unit member was reached.

Univariable analyses using chi-square tests were conducted to compare each of the outcomes rates and sociodemographic characteristics between the SMS and no SMS mobile telephone groups. In addition, to examine the representativeness of the two mobile telephone groups with regard to selected sociodemographic characteristics (prevalence (%) and 95% confidence intervals), comparisons were made against the Australian Bureau of Statistics (ABS) Census[156] data of people in paid employment (excluding self-employed).

Data analysis was conducted using SPSS Version 21.0.

6.5 Results

From the original sample of 9000 mobile telephone numbers, 3809 were ineligible due to being a non-connected number (1755), non-residential number (102), fax/modem connection (23), pager service (191) and the respondent being ineligible to participate in the survey (1738) (Table 6.1). Ineligible respondents were mainly due to being aged under 18 years (530) and either self-employed or not employed (1208). This left an eligible sample of 5191 mobile telephone numbers: 2566 that were sent a pre-notification SMS and 2625 that were not sent a pre-notification SMS.

A total of 526 eligible adults participated in the survey; 60.4% were sent a pre-notification SMS (318) and 39.5% were not (208). The response rate was 12.4% (RR1) for the mobile sample that was sent a pre-notification SMS and 7.7% for the sample that was not (Table 6.1). The SMS mobile telephone group had a higher cooperation rate (COOP1, 28.6% versus 16.0%) and a lower refusal rate (REF1, 27.3% versus 35.9%) compared to the mobile telephone group with no SMS.

The average time of the two surveys did not differ: 32.8 minutes (standard deviation=7.62) for respondents who received a SMS and 33.2 minutes (standard deviation=7.62) for those who did not.

Table 6.1: AWB Response rates: mobile telephone sample [using American Association for Public Opinion Research standards][75]

	No pre-notification SMS	Pre-notification SMS	P value
Interview (Category 1)			
Complete	203	317	
Eligible, non-interview (Category 2)			
Refusal and breakoff (terminated)	15	15	
Refusal	928	685	
Non-contact			
Respondent never available	1	2	
Answering machine household-message left	27	9	
Other, non-refusals			
Physically or mentally unable/incompetent	10	9	
Language problem	113	84	
Unknown eligibility, non-interview (Category 3)			
Always busy	2	0	
No answer	1326	1445	
Not eligible (Category 4)			
Fax/data line	9	14	
Disconnected number	891	864	
Special technological circumstances			
Pager	95	96	
Non-residential number	60	42	
No eligible respondent	820	918	
Total phone numbers used	4500	4500	
I=Complete Interviews (1.1)	203	317	
P=Partial Interviews (1.2)	0	0	
R=Refusal and break off (2.1)	943	700	
NC=Non Contact (2.2)	28	11	
O=Other (2.0, 2.3)	123	93	
Calculating e:	0.41	0.37	
UH=Unknown Household (3.1)	1328	1445	
UO=Unknown other (3.2-3.9)	0	0	
Response Rate 1 [& 2] I/(I+P) + (R+NC+O) + (UH+UO)	7.7	12.4	<0.001
Response Rate 3 [& 4] I/((I+P) + (R+NC+O) + e(UH+UO))	11.0	19.2	<0.001
Cooperation Rate 1 [& 2] I/(I+P)+R+O	16.0	28.6	<0.001
Cooperation Rate 3 [& 4] I/((I+P)+R))	17.7	31.2	<0.001
Refusal Rate 1 R/((I+P)+(R+NC+O) + UH + UO))	35.9	27.3	<0.001
Refusal Rate 2 R/((I+P)+(R+NC+O) + e(UH + UO))	51.2	42.4	<0.001
Refusal Rate 3 R/((I+P)+(R+NC+O))	72.7	62.4	<0.001
Contact Rate 1 (I+P)+R+O / (I+P)+R+O+NC+ (UH + UO)	48.3	43.3	<0.001
Contact Rate 2 (I+P)+R+O / (I+P)+R+O+NC + e(UH+UO)	69.0	67.2	0.27
Contact Rate 3 (I+P)+R+O / (I+P)+R+O+NC	97.8	99.0	0.02

e is the estimated proportion of cases of unknown eligibility that are eligible[75]. Enter a different value or accept the estimate in this line as a default. This estimate is based on the proportion of eligible units among all units in the sample for which a definitive determination of status was obtained (a conservative estimate).

Even though the toll-free 1800 number was given in the SMS, only seven people rang to opt-out of the survey. Statistics on the number of people using the 1800 number to query the survey were not recorded. When asked, 85.8% of the pre-notification SMS group remembered receiving a SMS about the study. There were no differences between males and females in the proportion of recall, however, recall was lower amongst respondents aged 18 to 24 years (80.5%) and 55 and years and over (81.4%).

When examined against the ABS Census population (Table 6.2), there were no differences in the two mobile telephone groups by sex. There was no clear pattern by age groups for either mobile telephone group, with some age groups close to the Census population. Even though the two mobile telephone sample groups did not differ to each other in terms of educational level and country of birth, both groups had a higher proportion of respondents with a bachelor degree or higher level of education and respondents born outside of Australia compared to the Census population. The SMS mobile telephone group had the same employment hours distribution as the Census whereas the no SMS group had a lower proportion of fulltime participants.

Table 6.2: Demographic profile by pre-notification SMS mobile telephone groups

	ABS Census employed	No pre-notification SMS		Pre-notification SMS		
	%	n	%	n	%	P value
Sex						
Male	50.1	104	51.2 (44.4 - 58.0)	160	50.5 (45.0 - 55.9)	0.87
Female	49.9	99	48.8 (42.0 - 55.6)	157	49.5 (44.1 - 55.0)	
Age groups						
18-24 years	15.2	32	15.9 (11.5 - 21.6)	41	12.9 (9.7 - 17.1)	0.22
25-34 years	24.4	41	20.4 (15.4 - 26.5)	81	25.6 (21.1 - 30.6)	
35-44 years	23.3	47	23.4 (18.1 - 29.7)	57	18.0 (14.1 - 22.6)	
45-54 years	21.9	53	26.4 (20.8 - 32.9)	79	24.9 (20.5 - 30.0)	
55-64 years	13.1	19	9.5 (6.1 - 14.3)	47	14.8 (11.3 - 19.2)	
65+	2.1	9	4.5 (2.4 - 8.3)	12	3.8 (2.2 - 6.5)	
Education level						
Bachelor degree or higher	23.8	83	40.9 (34.4 - 47.8)	115	36.3 (31.2 - 41.7)	0.29
Below bachelor level	76.2	120	59.1 (52.2 - 65.6)	202	63.7 (58.3 - 68.8)	
Country of birth						
Australia	72.4	132	65.3 (58.6 - 71.6)	218	68.8 (63.5 - 73.6)	0.42
Outside Australia	27.6	70	34.7 (28.4 - 41.4)	99	31.2 (26.4 - 36.5)	
Working hours						
Full time	70.4	120	60.9 (54.0 - 67.5)	220	70.7 (65.5 - 75.5)	0.02
Part time	29.6	77	39.1 (32.5 - 46.0)	91	29.3 (24.5 - 34.5)	

ABS: Australian Bureau of Statistics[156]

6.6 Discussion

The results of our study showed that sending a pre-notification SMS was effective in improving participation in population-based surveys using a RDD list of mobile telephones as the sampling frame. Although the absolute response rate was low, this feature increased the response rates (RR1) by 60%, cooperation rate (COOP1) by 79% and lowered refusal rates (REF1) by 24%. Our study contradicts other results in the literature, with our study indicating an improvement in response rates in the SMS mobile telephone group[215, 216, 221, 222]. A possible reason for this could be that this study was conducted in Australia and there could be different legal or legislation issues, and cultural differences in familiarity and ability in using SMS features in mobile telephones. In addition, the different payment system in Australia, whereby the researcher pays for both SMS and call to the participant, could make this methodology more

acceptable. In comparison, for example, in the US, the receiver of the SMS or call to the mobile telephone incurs the cost, not the sender or person making the call[224]. Therefore, the participants in our study were not refusing to participate because of cost. Three of these previous studies[215, 216, 222] were conducted over eight years ago (2004 to 2007) where the SMS features were most likely not as widely used or familiar, or a standard feature of the device. Also our participants were more likely to recall receiving the SMS (85.8%) compared to a recent study by DuBray (33%) which could explain why they found no differences in the response rates[221]. Although, Steeh et al[215] found no differences in the response rates, our findings were similar to theirs in terms of increased cooperation rates and decreased refusal rates.

This study is unique as it is the first of its kind in Australia, and its strength lies in its population approach using a large Australia-wide sample rather than a convenient sample. It is also timely and has been undertaken in a population which is more accepting of SMS in terms of usage and familiarity; in 2011, 78% of Australians who owned a mobile telephone regularly used SMS and this increased to 85% in 2014[218]. However, there are weaknesses associated with this study. Since our SMS was sent in English only and our study was limited to people who were currently employed, the majority were aged between 18 and 64 years, and therefore we cannot infer that the results are generalisable to the whole population. Up to 3% of Australians, 10 years and over, do not speak English well or not at all (2.5% do not speak English well or and 0.5% do not speak English at all (0.5%)[156], and an Australian study found that 3.7% of people aged 15 to 74 years had poor literacy skills (below Level 1)[225]. As Australia's population is linguistically diverse, with 400 languages spoken, including Indigenous languages, it is not possible to send SMS in different languages. It is not known for Australian migrants who do not understand English how they overcome these issues, but some migrants have use free online translation softwares, such as Google Translate®, or dictionary apps, such as Bing Translator® to overcome the language barrier. Given this, we can assume there still will be up to 3.7% of the population with poor literacy skills that

would not understand our SMS message and mostly likely not participate in general population surveys.

There are other limitations in regards to the application of using SMS for surveys. These include the additional cost in sending a SMS (0.10c per SMS) and administration, although this cost was lower than sending a PAL (paper, printing, postage and envelopes). To limit recall bias, the SMS was sent during the morning of the planned CATI telephone call. As a result, this created additional daily workload for administration staff. Feedback from the administration staff found the process relatively easy using appropriate software. Also, to minimise cost, the length of the message was limited to 160 maximum characters; any more would have doubled the cost per SMS (0.20c per SMS with maximum of 320 characters). This means, unlike the tradition PAL, our SMS did not include more detail about who was conducting the study, justify the nature of the study, the role of the respondent, the importance of the respondent's participation, and assurances of anonymity and confidentiality. The SMS method had an added benefit in providing the status of the mobile telephone number immediately after sending the SMS so that disconnected numbers could be removed from the sample saving costs in terms of interviewer time.

The concept of the pre-notification SMS is to eliminate the element of surprise or misunderstanding and to indicate that the call is legitimate. The SMS was also designed to overcome the problem of an unrecognised telephone number on the caller-ID that may be ignored. This is important in today's culture of increasing mistrust of unsolicited calls and provides the respondent the option to investigate the legitimacy of the incoming number if they wish. Unlike landline telephones, mobile telephones are usually attached to a person and not a household. Our study had a very small number of people using the toll-free 1800 number to opt out which might suggest that people did not feel suspicious about our study. General feedback from the interviewers found that pre-notification SMS made a minor impact on the respondents being more receptive or interested in the survey. We did not provide the option for the respondents

to reply by sending a SMS as this was seen as an easy way to opt-out and also to avoid nuisance or abusive SMSs.

It should be noted that this is a relatively new surveying area and the general population may not be familiar with receiving research market calls as they do on landlines. Furthermore, unlike other methods such as landline or online, mobile telephones have not yet been extensively overused by marketing companies and spammers. Continual monitoring of response rates for population surveys using a mobile telephone sample is required to see if the benefit is upheld. Using SMS is one feature of mobile telephones we can utilise. Mobile telephones are continually evolving with smartphones being the next generation that researchers can explore possibilities of incorporating other types of pre-notification messages such as links embedded to webpage with additional details of the study, voice messages in which the respondent can choose their language, and the use of multimedia message.

This study has shown the benefits of sending a pre-notification SMS with improvements in response and cooperation rates, and reduction in refusal rates, for population surveys using mobile telephones. Further research is needed to apply this method to incorporate the total population to determine if the results found in this study are generalisable to the whole of the population. In addition, given that mobile telephone technology is continually changing and the general population's behaviours are also changing with it, these studies need to be conducted regularly.

6.7 Appendix

6.7.1 SMS messages

SMS received from "Uni SA AWB".

Initial SMS:

> You have been chosen to participate in an important Australian Research Council survey. An interviewer will ring on 9999 9999. RSCHD 1800999999. Thank you.

Follow-up SMS:

> You have been chosen to participate in an important Australian Research Council survey. An interviewer will ring on 9999 9999. RSCHD 1800999999. Thank you.

6.7.2 Message left on answering machine

Hi, my name is ……. Calling on behalf of the University of South Australia. Sorry we missed you but we will tray calling again at a later date.

Chapter 7:   Discussion

7.1 Introduction

This thesis has shown from a series of studies that telephone surveys employing innovative techniques and using statistical methods can still be used to collect and report on chronic disease and behavioural risk factor surveillance systems in Australia. The uniqueness of this body of work lies in the detailed examination of the status of a current surveillance system by nonresponse, trends of nonresponse rates and coverage biases. This information was then and linked to possible solutions to address nonresponse bias, and improve the reliability and representativeness of health estimates. To arm health professionals, planners of health services and interventions, health promoters and policy makers with the best data possible, researchers in the area of chronic disease and behavioural risk factor surveillance need to be creative and innovative with the vast and continuing changing technology available, and to understand how people in society interact with these technologies. As argued by Johnson[226 p55], surveys are social activities and respondents are not "just autonomous information processors, rather they exist within complex social matrices that influences their thoughts, feelings and behaviours". As such, researchers need to take these issues into consideration as well as societal changes in their surveys. This thesis has shown that new statistical approaches to reduce biases in health estimates, such as raked weights, as well as innovated techniques, such as SMS, can improve representation and participation. With rising costs and increasing nonresponse, continual efforts must be made on multiple fronts and a single, simplistic survey methodology is becoming less feasible.

While the results and discussions of the studies will not be revisited *per se* (Chapter 3 to 6), this chapter will provide overarching comments on how this thesis has contributed significantly to the field of surveillance of chronic conditions and behavioural risk factors, as well as discuss the implications of the current methodologies used in Australia. This chapter will also discuss the limitations of this study as well as the possibilities for future research and present some recommendations for epidemiologists and researchers in the field

of chronic disease and behavioural risk factor surveillance in Australia regarding the use of CATI surveys.

7.2 Summary of findings

This thesis examined the feasibility of telephone surveying in Australia as a tool to collect representative information regarding health status and health risk behaviours, and was divided into two parts: firstly, describing the status of telephone surveys in Australia, and secondly, investigating potential solutions in the Australian and South Australian context.

The first research question was "w*hat is the current status and biases of telephone survey methodology in Australia related to sampling frames and nonresponse biases?*" The following two hypotheses address this research question and are investigated in Chapters 3 and 4 of this thesis:

H_1: There are differences in terms of sociodemographic, health status and health risk behaviours for people living in mobile only households compared to people living in landline and mobile households, or landline only households.

H_2: The declining response rates over the last 12 years have changed the representativeness of household (telephone) surveys.

Coverage of telephone (landline and mobile) ownership in South Australia is very high (97%), with nearly a third of households mobile-only (27.8%), and only half of households (49.0%) have either a mobile or landline number listed in the White Pages telephone directory. Further, the proportion of mobile-only households (27.8%) is increasing and does not appear to have reached a plateau. This corresponds with the decrease in landline telephone coverage and also the increase in nonresponse rates in telephone surveys (Chapter 4), with refusals and inability to establish contact (no answers) being the main reasons for nonresponse.

These studies are important because they quantify the *current* potential biases from the various landline-based telephone sampling frames used in Australia and the population groups that are potentially excluded. Technology is evolving and changing fast. This evolution is influencing our society and we are witnessing an adaption to these technologies and, consequently, has had an impact on sampling frames and participation. It has been suggested that surveys are a reflection on subtle shifts in societal norms[69]. They demonstrate that some sociodemographic groups, for example, older people, females and retirees, are increasingly being over-represented in SAMSS, and other groups, such as younger people, males, fulltime workers and renters are increasingly being under-represented over time. The results of this thesis indicate that SAMSS has been becoming less representative over time and some of the estimates of health indicators such as current smokers are potentially biased. Other health estimates such as arthritis, diabetes or obesity did not vary within SA over time. Our results show that mobile-only respondents are different across a range of sociodemographic indicators, similar to international studies[62, 110, 146]. As stated in these chapters, there is a need to continuously assess the methodology of population health telephone surveys due to the rapid technological changes in telecommunications. There is also a need to continuously assess the different 'user cultures' associated with the use of these new and old telecommunication technologies. As Stern et al.[227 p294] points out, researchers cannot "solely rely on what is coming toward us without understanding the principles of effective surveying we have developed through decades of research". As such, this thesis has provided a relatively up-to-date view of the current situation. Notwithstanding, ongoing assessment will be required.

The second research question was "*can methods such as raked weighting and innovative techniques using SMS be potential solutions to reducing bias in telephone survey sampling frames and nonresponse biases in Australia?*" Chapters 5 and 6 addressed this research question by examining the following two hypotheses:

H3:   Raked weighting statistical methodology will reduce the biases in health status and health risk behaviour estimates due to nonresponse and under-coverage.

H4:   Using text messages can increase participation in mobile telephone surveys in Australia.

Chapter 5 showed that when using the statistical weighting approach, raked weight that incorporate a range of sociodemographic variables can reduce bias in health and behavioural risk factor estimates in telephone surveys caused by nonresponse and sampling coverage problems. The findings in Chapter 3 and 4 further support the need to include additional sociodemographic variables (such as dwelling (rent versus other) and employment status) in nonresponse statistical adjustments (such as raked weights, propensity modelling, or imputation methods) to address the under-representation of some population groups in SAMSS.   As shown in Chapter 3, health estimates with higher prevalence among socioeconomically disadvantaged households or younger people, can be under-estimated in telephone surveys because of nonresponse bias (non-coverage and lower response rates). Indeed, Chapter 5 demonstrated substantial changes in the health estimates for current smokers, food insecurity, mental health conditions, fair or poor health, and those not sufficiently active after raked weights were applied. These estimates changed considerably with the addition of dwelling status (rent versus other) in the raked weights, hence reducing the bias. However, as the proportion of mobile-only households and households with no listings in the telephone directory are continuously increasing, as shown in Chapter 3, other efficient sampling strategies for chronic disease and behavioural risk factor surveillance systems may need further research into how to include sociodemographic groups that are under-represented in telephone surveys.   As it stands, to include mobile-only households in the sample frame, the currently suggested RDD Australia-wide sample of mobile telephones without a geographical marker, as discussed in Section 3.3, are not feasible or sustainable and are too costly for use in SAMSS and similar states.

Chapter 3 showed that close to 30% of the Australian population were living in mobile-only households and this proportion is increasing. It also showed that people in mobile-only households are demographically different from households with a landline telephone (including households with landline and mobile telephones), across a range of sociodemographic indicators. Given that mobile-only households are excluded from the current landline sampling frames, various surveillance systems in Australia employ dual-frame sampling frames that incorporate a RDD sample of mobile telephones as well as a landline sampling frame. However, the response rate of mobile telephone surveys was very low in these studies. The directory-listed sampling frames also consist of mobile telephone numbers. From these sampling frames, it is evident that there needs to be another technique to encourage people with a mobile telephone to participate in surveys, based on current experiences with landline telephone surveys. The experimental study in Chapter 6 demonstrated that sending a pre-notification SMS was effective in improving participation in population-based surveys using a RDD list of mobile telephones as the sampling frame. Although the absolute response rate was low, this approach increased the response rate (RR1) by 60%, the cooperation rate (COOP1) by 79% and lowered the refusal rate (REF1) by 24%. This unique and cost-effective study can potentially be used to further explore innovative ways of utilising mobile telephone technology. It also demonstrated that a high proportion of those completing the survey recalled receiving the message. Researchers should therefore look into ways to utilise SMS technology as a cost-effective strategy, as opposed to apportioning limited resources in collecting information via interviewer-administered mobile telephone surveys, to include mobile-only households.

7.3 Study limitations

This thesis has demonstrated that using two different methodological techniques can improve participation in, and produce more reliable health estimates from chronic disease and behavioural risk factor surveillance systems. However, the analyses undertaken in the study used only one surveillance system in Australia and one type of sampling frame (i.e. directory-

listed). It would be interesting to examine possible improvements in health estimates if raked methodology was also applied to the surveillance system in New South Wales, which has historically used RDD landline telephones numbers, and dual RDD sampling frames of landline and mobile telephones[158] since 2012, as well as Western Australia[13], which uses directory-listed sampling frames. Similarly, the trend analyses of the nonresponse rates and the examination of the representativeness of the surveillance system over time was limited to South Australia. Again, two of the states in Australia began their surveillance system at the same time as SAMSS, and similar analyses should be undertaken and documented for comparison. By comparing surveillance systems with similar nonresponse rate calculations and demographic comparisons, results can highlight the successes and failures of different methodologies used in each state.

This thesis focused on two key sources of unit nonresponse: declining participation due to refusal and no one answering the telephone call, and non-coverage of sampling frame mainly due to unlisted telephone numbers and mobile-only households. There are other forms of bias[64, 66, 67] that have not been the focus of this thesis, including missing responses to questions due to unable (don't know) or not willing (refusing) to answer, the reduced quality of answers due to socially desirable responses, engaging in other activities while being interviewed, censoring answers because of lack of privacy (people listening), or the tendency to satisfice by providing the same response category option for a series of items[228-230]. These are important as there is some evidence that these issues are influenced by survey mode[64] and as more surveillance systems are exploring options of using mixed-modes or methods, care must be taken in translating questionnaires across modes.

Harmonising data items, as in the WHO STEPwise approach[231], or survey methods across Australia was not a focus of this thesis. As a consequence, it was difficult to compare between states and territories in Australia and over time, since some state-based surveys like SAMSS are conducted monthly[11-13], whereas others are conducted annually[49, 50]. It should be noted that the states

and territories throughout Australia are not homogenous as each are shaped by different sociodemographics profiles, population sizes (7.5M in New South Wales, 5.8M in Queensland, 1.7M in South Australia and 0.3M in Northern Territory)[114] and governing structures. As such, survey methods that are suitable in one state may not be possible or feasible in another.

7.4 The future of chronic disease and behavioural risk factor surveillance systems

Since this thesis was undertaken four years ago in 2012, the field of telephone survey methodology has progressed and evolved. The issues covered thus far are still relevant, but other emerging themes are arising and need to be considered for future research. The following sections highlight a few possible themes, but do not represent an exhaustive list.

7.4.1 Big data

With the growth of technology in all areas of society, there is an exponential growth in digital data through everyday transactions in banking, to shopping, health care and internet activities. As a result, large disparate volumes of data are accumulating, often referred to as 'big data', that are complex and possibly linkable[232-234]. Big data is described as containing volume, variety (data from various sources), velocity, variability, veracity (quality of the data) and value[235]. Potentially, big data can be converted into new forms of analyses and information. It can be thought of as multidisciplinary since data can potentially be sourced from health systems, government records, media, education and industry. Big data is divided into two broad areas: structured (for example Census, business transactions, eHealth) and unstructured data. Unstructured data are from sources such as social media (tweets, texting, facebook), emails, photos, search engines (Google), wearable devices (smart watches, fitness monitors) and activities recorded from smart phones such as sleep and movement tracking, which have additional geographical location information[19, 236, 237].

It has been estimated that 80% of big data is unstructured and the challenge is to convert raw unstructured information into meaningful formats that is suitable for analyses, to produce relevant information[233, 235]. The main focus in the use of big data in health care has been around management of health care and its associated costs; assisting in clinical decision making; providing clinical information in real time; adverse events from medication; vaccinations and medical procedures; and the surveillance of infectious diseases[236-239]. Medical data are increasingly moving into digital formats, such as the South Australian Enterprise Patient Administration System[240], which is being developed to replace paper-based medical records. Big data can provide an opportunity to produce small area estimates which is not always possible with current chronic disease and behavioural risk factor surveillance systems[241]. It also presents the opportunity to undertake novel and unique approaches in uncovering patterns in health conditions, enabling better allocation of resources and targeted interventions[237, 242].

So can big data replace surveillance systems? Currently, big data are reliant on convenient observational data which can be biased[243] or poor quality[233] (such as administrative records), since the purpose of the data is not to observe epidemiological trends or associations. There is the potential for false alarms and spurious correlations through automated data analytics, machine learning or network mapping[187, 232, 233, 244]. Therefore, a stronger epidemiological framework and theory is required for the information to be valuable, useful and meaningful[233, 236, 244]. Big data cannot provide the contextual information that can be asked in general surveys, such as subjective questions like general health, mental health and wellbeing, suicidal thoughts; opinions, attitudes, and knowledge of public health activities; and barriers to health services[237, 244].

Big data can enhance and complement chronic disease and risk factor surveillance systems, however they cannot replace them. Surveillance systems can be potentially linked to a variety of data sources and this has been demonstrated in many surveys[13, 245-247]. These methods are challenged by the appropriate hardware and software tools available to analyse the large amount

of data that is being generated[238]. Even though surveillance systems like SAMSS are considered 'small data', it have the potential to be big data[248]. More research, resources and collaboration is needed to enhance chronic disease and behavioural risk factor surveillance systems by establishing linkages to structured and unstructured data[246, 247]. Australian surveillance systems need to be proactive in this area and address issues around consent, confidentiality, ethics and privacy.

7.4.2 Emerging technological trends in mobile telephones

As stated previously, as technology evolves, so do societal values and the way people communicate. As the cost of these technologies become more affordable, including smartphones and internet or broadband costs, more services are becoming automated and available online, such as paying bills, online banking, making appointments, registration, booking tickets, and even people using social media or SMS to converse with each other as opposed to talking directly over the telephone[227]. This could be the reason why people are less tolerant of researchers calling on the telephone[227]. This increasing acceptance of the change in the way people communicate in society has led to the need for surveillance systems to adapt their methodologies to reflect these societal changes. In addition, as people are increasingly competent and become more reliant on mobile technology, they could be more accepting of researchers engaging them via these methods as highlighted via the SMS research undertaken in this thesis[249].

Mobile telephones are more than just a communication device for talking; they are a multimodal device[161]. Use of mobile telephones are almost at saturation point of around 96.3% (as found in Study 1 in this thesis) and more people are replacing their mobiles with smartphones (74% of Australian adults in 2015[218]). The challenge for researchers is to exploit the many features of this technology to engage people in participating in chronic disease and behavioural risk factor surveillance systems[129]. Even though mobile telephones traditionally have low response rates[116, 128] there is potential to undertake

variations of surveys using SMS as demonstrated in our study in Chapter 6 and also given that people reported to use SMS regularly (85%)[218].

Many studies have examined the use of SMS as a way to engage people in completing online surveys and a way to incorporate mobile telephone samples in a cost effective way[250-252]. Over the last few years, mobile telephone screens are increasing in size, which makes it more attractive to conduct online surveys via smartphones[253]. The use of apps has also been explored[254] such as *time-use* apps which have demonstrated a unique way of recording regular activities instead of writing in a diary[255]. The most common method is sending an SMS, with a link to an online survey, to invite or recruit people to complete the online survey[128, 250, 252, 256, 257]. This approach is ideal since people tend to check their mobile telephone regularly and the sending of a large number of SMS with followup SMS reminders is relatively easy and cost effective. It should be noted, as shown in our study in Chapter 6 and in other studies, that the participants are younger in these types of studies[252], and this method may not be acceptable for all groups in the community[126, 129, 250, 252]. There is still the question of the quality of the data and the proportion of terminations (or breakoffs) that are produced via mobile telephone surveying[253, 258]. It is dependent on the attention level since users are likely to be on the go, multi-tasking or 'killing time' and the quality of the responses will be based on the experience of the participant in handling data entry in this form[129, 250, 251]. Care needs to be taken when using different modes as the responses may vary between verbal (via landline or mobile) and online surveys[259], and an existing CATI format may not always translate well to an online mobile telephone format, particularly as there are many different models and operating systems[129, 253, 260, 261]. Therefore, these type of surveys need to be kept short and simple, and include the option of completing the survey in stages[260], with an interface design that is acceptable to the respondent and available on different mobile models[129, 256, 261]. As such, the traditional 15 minute data collection period associated with the current SAMSS questionnaire would be problematic and potentially need to be shortened considerably.

7.4.3 Mixed-mode or mixed methods approach

Various studies have considered using a mixed-mode approach to increase participation and to include mobile only households in the sample[142, 159]. Mixed-mode is where another mode such as mail or internet is conducted to complement the traditional telephone survey. The idea of using a mixed-mode approach is to mitigate limitations of each individual mode, such as different coverage, non-response and cost issues[73, 262]. There are many types of mixed-mode approaches, as outlined in Dillman & Tarnai[73 pg 512]: generally by collecting the "same data from different sampling frames in the same population for combined analysis" or collecting the "same data from different respondents within the same sampling frame". One study used two modes: telephone and mail, and used a database that consisted of residential addresses as the sampling frame in an attempt to include respondents from mobile only households[159]. However, they found that the groups that were under-represented in telephone surveys were also under-represented in the mail surveys[159]. Mobile web-based surveys are increasingly being considered as an alternative method[127]. Studies investigating mobile web surveys have found lower response rates and high break-offs, but also younger respondents and a good level of data quality (low measurement error)[127, 252].

These alternative modes introduce other issues and the design of each mode needs to be taken into consideration. The questionnaire design for CATI surveys can include specific features, for example complicated skip patterns to filter out non-relevant responses to subsequent questions as well as edit checks (range or consistency checks to reduce data entry errors). These needs to be carefully considered in other modes such as mail surveys[160]. CATI wording needs to be clear, concise and short, and cannot have visual aids such as prompt cards which can be used in face-to-face or online surveys (e.g. an illustration to show a standard glass of alcohol such as a glass of wine, a nip of spirits, or a schooner of full strength beer)[61]. Operational differences can have an impact on how the questions are answered. Telephone surveys are mainly interviewer-administered compared to mail or online-based surveys which are self-administered, and this can lead to different responses[73, 160]. In telephone

surveys, the interviewer has control over who is the selected respondent within the household, whereas in the mail or online surveys any member of the household can determine who responds to the survey [142]. Modes vary with level of privacy which is high with mail or online surveys compared to a moderate level of privacy with telephone surveys (others listening in making it difficult to answer sensitive questions)[161]. Mail surveys require a longer data collection period compared to the allocated monthly time period for telephone surveys. The main issue with mobile online-based surveys is the design of the survey that can be optimised for different types of mobile telephones with various capabilities, screen sizes and the quality (strength) and speed of the internet[256].

As mixed-mode approaches are considered for surveillance systems, the challenge is how to incorporate the alternative modes that maintain the timeliness, flexibility and low cost of the system[142]. It should also be noted that mixed-mode approaches may address issues regarding coverage of sample frames and possibly the representativeness. However, these methods do not solve the problem of declining participation in surveys[141]. Notwithstanding these limitations, future chronic disease and behavioural risk factor surveillance systems can explore mixed-mode methodology to address the issue of coverage issues with telephone sampling frames and nonresponse.

7.4.4 Panel surveys – an alternative sampling frame

To overcome the coverage and nonresponse biases in current sampling frames, panel surveys have been considered as an alternative in regular surveys[263, 264]. Panel surveys are groups of participants recruited by various methods who have agreed to participate in a series of studies for renumeration[265-267]. Renumeration can be cash or PayPal reimbursements, online merchant gift codes and redeemable points, frequent flyer points, or deposits to credit-card accounts[267]. Samples are drawn from the panel to meet the specific needs of the study depending on topic or group[267]. Panel surveys can be divided into two groups: probability-based, and nonprobablity-based or volunteered

panels[265, 266]. Probability-based panels are preferable since the probability of selection from the general population is known[266, 267]. Probability-based panel surveys are usually pre-recruited panels whereby participants are recruited using probability sampling methods from different modes such as landline or mobile telephone, face-to-face or mail surveys with the same intensity of callbacks and primary approach letters to obtain high participation rates and lower nonresponse rates[268]. Panel surveys are seen as a cost-effective approach to reduce non-coverage bias[263] and the sample can be used to select potential participants based on specific characteristics from the panel. Given that South Australia is a much smaller population relative to the rest of Australia (7% in 2014)[114], panel surveys can be seen as an alternative sampling frame to compensate for the mobile-only population, or by means of dual-frame or mixed-mode methodology to improve coverage[263] and to produce reliable estimates. As long as the foundation of recruiting into the panel survey is epidemiologically and statistically valid, with the appropriate weighting methodology[264] then panel surveys could be an alternative sampling frame for surveillance systems.

7.4.5 "Looking back in order to go forward": analytical techniques

A chapter in the book, *Global Behavioral Risk Factor Surveillance*[269], highlighted the importance of data analyses and dissemination of chronic disease and behavioural risk factor surveillance systems. The focus of this thesis was to examine the methodological issues around data collection in the context of chronic disease and behavioural risk factor surveillance systems. As demonstrated in this thesis, there is a plethora of studies covering a broad spectrum of methodological issues from question design, sampling frame, mode of survey, to statistical adjustments. With the increased computer power and skills over the last 15 years, more sophisticated analyses and dissemination techniques have been explored. However, many of these surveillance systems have not utilised the dynamic nature of surveillance systems to examine trends. Many systems report descriptive estimates, such as frequencies or crosstabulations[269], or aggregate the data to analyse the trend, thus losing the

information in the variability between the observations[14]. For example, a method by Assaf et al (2015)[270] proposed using varying coefficient models on Italian and BRFSS data[270, 271], to investigate which subgroups in the population had improved or deteriorated over time with respect to the health indicator. These analytical approaches are more informative for health professionals and promoters, and assist to target interventions more efficiently.

The other big challenge for chronic disease and behavioural risk factor surveillance systems is the emerging area of automated analytics. Automated analytics or data-mining tools have been around for many years with the rise in big data. For example, crosstabs and correlations, on a range of health indicators by various sociodemographics and behavioural risk factors could be automated and presented visually. As stated in Section 7.4.1, there is potential for surveillance to link with other data sources such as hospital and community services, medications, educational institutions and police. The challenge for public health practitioners and epidemiologists who use these systems, is how to apply these automated analytics to chronic disease and behavioural risk factor surveillance systems while upholding the traditional epidemiological foundations[239, 242, 272], and to support decisions for health professionals and administrators, by informing health promotion activities and interventions.

These analytic approaches need to be explored with vigour so that the analysis and interpretation component of the definition of surveillance is fully exploited.

7.5   Way forward

This thesis has provided evidence regarding the current issues and potential solutions facing chronic disease and behavioural risk factor surveillance systems in Australia, and the South Australian system (SAMSS) in particular. Chapters 3 to 6 have identified the current issues and identified some solutions in addressing nonresponse and coverage that surveillance systems can implement, with the use of statistical methods and applying a cost-effective technique of SMS to increase participation in mobile telephones. However, as

technology and society are continuously changing, chronic disease and behavioural risk factor surveillance systems need to continuously monitor these issues at the same time as investing in emerging areas, as identified in Section 7.4. These need to be considered with appropriate allocation of resources, funding and suitable collaboration.

This thesis has highlighted areas that chronic disease and behavioural risk factor surveillance systems can currently coordinate and implement. Research in New South Wales and Victoria has demonstrated that adding a mobile telephone sampling frame is essential for improving coverage in South Australia. However, the current methodology that is being used could be feasible for a one-off survey with a large budget, but it is not practicably feasible and would be costly for SAMSS. Therefore, collaboration is needed across the jurisdictions to pool resources to share the national-wide RDD mobile telephone sampling frame, as a way protecting the interests of each state and territory.

In Australia, researchers have been slow to adopt standardised nonresponse rates such as those recommended by the American Association for Public Opinion Research (AAPOR)[75]. Australian studies and surveillance systems should evaluate nonresponse biases[101] and publish regularly to inform users of the performance of the systems. By undertaking these type of analyses, informed decisions can be made about appropriate data analyses or adjustments to the data such as raked weights that go beyond the usual limited demographics.

As stated in Chapter 3 and Section 7.4.2, increasingly more and more households and individuals are moving towards solely owning a mobile telephone and disconnecting their home-based landline. The way people are using their mobile telephone has also increasingly provided them with more control over who can approach them[161]. This thesis has demonstrated that participation in mobile telephone surveys is very low, and using SMS features can improve participation. However, there are other avenues of mobile technology that warrant further investigation, such as online mobile telephone

surveys. Studies need to explore what is acceptable to the Australian population in terms of chronic disease and behavioural risk factor surveillance systems[161] and how the current format of SAMSS can be translated into mobile telephone technology. Many factors need to be considered such as terminations, nonresponse, mode differences and cost implications.

Another approach that might be suitable for states with small population sizes like South Australia, is to investigate other sampling frames for chronic disease and behavioural risk factor surveillance systems such as probability-based panel data in mixed mode methods. Few studies have complemented their landline telephone samples with panel samples in their existing period surveys[263, 264]. Regarding epidemiological studies, Australia has been slow to explore this possibility as an alternative sampling frame. Caution needs to be maintained as researchers need to understand the sampling strategy used to create these panel data in Australia and the practice of incentives which is not currently an acceptable technique in epidemiological studies in Australia.

Big data and data linkage is emerging as the new frontier of information and data analyses. As stated in Section 7.4.1, chronic disease and behavioural risk factor surveillance systems can potentially be linked to a variety of data sources, and can build on current experiences in SAMSS. In SAMSS, there is a question regarding followup of respondents for foodborne disease outbreaks so that SAMSS participants can be matched to outbreak cases by age, sex and postcode (85.4% agreed to followup in 2012)[11]. Following this, permission was obtained from SAMSS respondents to assign geographical coordinates (geocode) to the participant's residential address to enable the information to be mapped. In 2012, around 72.2% agreed[11], and this methodology has been successfully used in a number of studies[246, 247]. Given this success, additional research is needed to explore obtaining further information such that SAMSS data can be linked to a variety of government records (hospital, education etc) to enrich the surveillance system. This is a seen as a cost effective means of adding information. As stated in Section 7.4.1, discussion with stakeholders and data custodians on resources, funding, legality, access and feasibility but also

public engagement and consultation about privacy and confidentiality, should be undertaken.

This thesis has also identified that nonresponse is the biggest threat to current chronic disease and behavioural risk factor surveillance systems. As Massey & Tourangeau[273 p235] point out, the "lack of public recognition for the importance of statistical and scientific surveys" is contributing to nonparticipation and there is a need to "improve the image" of surveys. This can be done by marketing to all sectors of society explaining the importance of participating in surveys, the reason why we use these approaches, how the findings are used to improve health.

One issue that was raised in the big data section is improving accessibility of surveillance data and dissemination. There is a need for users other than data custodians to gain access in a timely manner for other purposes while maintaining confidentiality and integrity of the data to conduct research that would be useful for informing policy and interventions[274]. By encouraging data sharing and usage, and the opportunity of linking surveillance data to other data sources, there is the potential for novel analyses and findings to improve health and management of health conditions.

Although not in the scope of this thesis, many of these issues require a coordinated approach and collaboration between states and various government departments or organisations. This is very important for small states with limited budgets. In Australia, there is no overarching group for these issues to be discussed, like the now disbanded CATI Technical Reference Group (TRG)[56, 275], which was an advisory committee to the National Public Health Information Working Group under the National Public Health Partnership. The CATI TRG had representation from state and national governments, institutes and universities, and was created to discuss methodological issues. The CATI TRG was instrumental in bringing about the different continuous and periodic chronic disease and behavioural risk factor surveillance systems, as well as developing harmonising tools and discussing methodological issues such as

telephone sampling frames, while maintaining local needs. The international groups, World Alliance for Risk Factor Surveillance (WARFS), is an informal international network to support the development and continual relevance of behavioural risk factor surveillance systems, and to facilitate collaboration between and also within countries[276]. However, a group similar to CATI TRG is required to address some of current and emerging issues, in the Australian context, that are confronting chronic disease and behavioural risk factor surveillance systems, but also to reduce duplication in research and to share findings. To assist in maintaining these groups, administration funding and resources are required.

7.6 Conclusion

Chronic disease and behavioural risk factor surveillance in South Australia, formulated on probability-based telephone survey methods, can still be a reliable, efficient and cost effective tool for health professionals, planners of health services and interventions, health promoters and policy makers in providing evidence with the aim of reducing the impact of chronic disease in the community. This thesis has focused on two areas of telephones surveys: the consequences of the increasing trends in nonresponse, and new techniques in improving the estimates in chronic disease and behavioural risk factor surveillance systems. It has shown that there is evidence of increasing potential for bias to affect estimates from SAMSS and other similar Australian surveillance systems, and has provided evidence of statistical methods, such as raked weighting methodology, that can be implemented to improve the representativeness of health estimates. Among the possible methodological innovations, such as raked weighting methodology or pre-notification SMS to increase participation, are feasible from a resourcing point of view, for states and territories in Australia, like South Australia, that have comparatively lower funds available and limited resources.

Surveillance systems need to be flexible and always evolving to accommodate technological and societal changes. The vast and rapid changes in

telecommunications technology, and changes in the way society interacts as a result of these technologies, has altered the landscape of telephone surveys. Researchers need to apply a level of caution in modifying current surveillance systems to new methods and to apply conservative approaches in order maintain comparability with past methods. Analysis and communication strategies need to be developed so that findings are not attributable to methodological changes, but to actual changes in trends in the population.

A recent paper by Kuller (2016)[277 pg 376], states that "the success of epidemiology should be judged as it was in the past, by its relevance to public health and preventive medicine". This could be said of chronic disease and behavioural risk factor surveillance systems; the success is in the purpose of the system which is to provide the evidence for the planning, implementation and evaluation of public health practice by tracking health indicators for the prevention of NCDs. Researchers must ensure that resources are financed into all levels of the surveillance, not just in one area such as sampling frames and data collection, while neglecting other innovative, efficient and cost effective methodologies to obtain reliable estimates. Surveillance systems require investment in continual evaluation in terms of nonresponse rates and coverage biases, and to use this information to develop innovative techniques and statistical methods with the aim of producing reliable and representative health estimates. By applying these simple solutions, such as raked weighting methodology, to overcome nonresponse biases and decreased participation, telephone surveys can still be used to collect and report on information on chronic diseases and behavioural risk factors in Australia.

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APPENDIX 1: SOUTH AUSTRALIAN MONITORING AND SURVEILLANCE SYSTEM (SAMSS) QUESTIONNAIRE 2011 VERSION

Note : text in bold black font is read out

TIME OF SURVEY

DEM1   Enter Year

(Single Response)
1. *Enter Year*   __ __

DEM2   Enter month
(Single Response)

1. January
2. February
3. March
4. April
5. May
6. June
7. July
8. August
9. September
10. October
11. November
12. December

INTRODUCTION

Intro 1 : Call for the first time

Good .... My name is .... and I am calling on behalf of the University of Adelaide in collaboration with SA Dept of Health. We are conducting a survey about the health needs of South Australians.

Intro 2 : Receiving the letter

We recently sent you a letter telling you about the survey. Did you receive the letter?

(Single Response)
1. Yes
2. No
3. Don't know

Interviewer note: If respondent did not receive the letter, Interviewer to offer to either read it out over the telephone or to send out a copy in the mail.

SELECTION OF RESPONDENT (DEMOGRAPHICS)

This survey includes children aged less than 16 years living in the household where a parent or guardian answers these health questions on their behalf. To ensure that we get a good representation of the community, could you please tell me

DEM3   **Age of respondent**

(Single Response. Enter 999 if not stated)
1. *Enter year*   ___
2. *Enter months*   ___
3. *Enter weeks*   ___
4. Not stated   [999]

Sequence guide: If AGE < 16 years Go to IntroA2

DEM4   **Which age group [are you / is the person who was last to have a birthday] in? Would it be**

(Read Options. Single Response)

1. **0 to 5 months**
2. **6 to 11 months**
3. **1 year**
4. **2 years**
5. **3 years**
6. **4 years**
7. **5 to 9**
8. **10 to 11**
9. **12 years**
10. **13 to 15**
11. **16 to 19**
12. **20 to 24**
13. **25 to 34**
14. **35 to 44**
15. **45 to 50**
16. **51 to 54**
17. **55 to 64**
18. **65 to 74**
19. **75 years or older**
20. Not stated   [999] ***Terminate***

Sequence guide: if AGE < 16 years Go to IntroA2

IntroA1   Are you that person in the household who was last to have a birthday?

Interviewer select the appropriate type:
1.   Yes - speaking
2.   No - somebody else
3.   Foreign language interviewer required   ***Enter language***
4.   Refusal   ***Enter reasons***

Intro 3 : Confidentiality and assurance

I can assure you that information given will remain confidential. The answers from all people interviewed will be gathered together and presented in a report. No individual answers will be passed on. And before we start, I just need to let you know that this call may be monitored by my supervisor for training and coaching purposes.

Sequence guide: If IntroA1 = 1, Go to NS
If IntroA1 = 2, repeat Intro 1, 2 & 3, clarify age, then Go to NS

IntroA2   Would you be the most appropriate person to answer questions on their behalf?

(Single response)
1.   Yes
2.   No

Intro 3 : Confidentiality and assurance

I can assure you that information given will remain confidential. The answers from all people interviewed will be gathered together and presented in a report. No individual answers will be passed on. And before we start, I just need to let you know that this call may be monitored by my supervisor for training and coaching purposes.

Sequence guide:
If IntroA2 = 1, Go to IntroA3 (Q0)
If IntroA2 = 2 Either
a) Get the person & repeat Intro 1, 2 & 3, clarify age, Go to IntroA3
b) Make an appointment to call back later (within 24 hours)

IntroA3   Because we are going to ask questions about this child, would you mind telling me this child's first name so that we can use this during the interview?

(Single response)
1.   *Yes, enter name*
2.   Refused

IntroA4   Could you please tell me your relationship to [child's name]?

(Single response)
1.   Mother
2.   Father
3.   Step-mother
4.   Step-father
5.   Other relative
6.   Other (specify)

INITIAL DEMOGRAPHICS

DEM5   Gender of respondent or child

(Single Response)
1.   Male
2.   Female

DEM6   Including yourself how many people aged 16 years and over live in this household?

(Single Response. Interviewer note: enter number of people 16 years and over)
1.   *Enter number*   ____
2.   Not stated   [999]

DEM7   How many children (including babies) under 16 years live in your household?

(Single Response. Interviewer note: enter number of people 16 years and over)
1.   None   [0]
2.   *Enter number*   ____
3.   Not stated   [999]

OVERALL HEALTH STATUS

Sequence guide: If AGE < 5 go to NS

This first question asks for your views about [your / *child's name*] health.

SF1 In general, would you say [your / *child's name*] health is:

(Read Options. Single Response)

1. **Excellent**
2. **Very good**
3. **Good**
4. **Fair**
5. **Poor**

HEALTH CARE UTILISATION

SER6   In the last 12 months, how many times have you/ has child's name] used a general practitioner in South Australia?

(Single response. Interviewer note: enter 0 = none, 998 = don't know, 999 = refused)

1. Enter No. of times   ____
2. None   [0]
3. Don't know   [998]
4. Refused   [999]

Sequence guide: if SER6 = 0, (has not visited a GP in last 12 months go to SER1.2

SER1   In the last four weeks, how many times [have you / has child's name] used these health services in South Australia?

(Read Options. Multiple Response. Interviewer note: Enter 99 if none, 990 don't know & 999 if refused)

1. **General Practitioner**   ___
2. **Hospital - Accident & Emergency department**   ___
3. **Hospital admission**   ___
4. **Hospital - Clinic (outpatient, specialist or other clinic)**   ___
5. **Specialist doctor (not in hospital)**   ___
6. None
7. Refused

Sequence guide: If age < 16 Go to NS

SER3   [In the last four weeks, how many times [have you / has child's name] used these health services in South Australia?]

(Read Options. Multiple Response. Interviewer note: Enter 99 if none, 990 don't know & 999 if refused)

1. **Psychologist**
2. **Psychiatrist**
3. **Other community mental health services**
4. None
5. Refused

CO-MORBIDITY, INJURY, DISABILITY (Health Status)

Sequence guide: If AGE < 2 Go to (COM1)

DIA1   [Have you / has child's name] ever been told by a doctor that [you have / he has / she has] diabetes?

(Single Response)

1. Yes
2. No
3. Don't know/Refused

Sequence guide: If DIA1 = 2,3 Go to AST5

DIA10   How old [were you / was your child] when first diagnosed with diabetes?

(Single Response)

1. Enter age   ____
2. Don't know / refused

Sequence guide: If AGE $\geq$ 16 & SEX = 1 Go to DIA4
If AGE 2 -15 Go to DIA5
If DIA10 $\geq$ 45 Go to DIA4

DIA2   Were you pregnant when you were first told you had diabetes?

(Single Response)

1. Yes
2. No

Sequence guide: If DIA2 = 2 Go to DIA4

DIA3   Have you ever been told by a doctor that you have diabetes other than when you were pregnant?

(Single Response)

1. Yes
2. No

Sequence guide: If DIA3 = 2 Go to AST5

DIA4   Have you got diabetes now?

(Single Response)

1.   Yes
2.   No

DIA5   [Other than the diabetes when you were pregnant] What type of diabetes [were you / was child's name] told [you / he / she] had?

(Single Response)

1.   Type 1 – Insulin dependent – Juvenile onset
2.   Type 2 – Non-insulin dependent – Mature onset
3.   Don't know
4.   Other (specify)

AST5   [Have you / has child's name] ever been told by a doctor that [you have / he has / she has] asthma?

(Single Response)

1.   Yes
2.   No
3.   Don't know

Sequence guide: if AST5 ≥ 2 go to AST7

AST10   How old [were you / was your child] when first diagnosed with asthma?

(Single Response)

1.   Enter age   ____
2.   Don't know / refused

AST7   Symptoms of asthma include cough, wheezing, shortness of breath and chest tightness.

During the past 12 months, did [you / child's name] have any symptoms of asthma?

(Single Response)

1.   Yes
2.   No
3.   Don't know

AST3   During the past 12 months, did [you / child's name] take asthma medication that was prescribed or given to you by a doctor? This includes using an inhaler, puffer or nebuliser.

(Single Response)

1.   Yes
2.   No
3.   Don't know

AST8   Have [you / child's name] had wheezing or whistling in [your/his/her] chest at any time in the last 12 months?

(Single Response)

1.   Yes
2.   No
3.   Don't know

Sequence guide: If AGE < 16 Go to COM1
    If AST5 ≥ 2 Go to COP3

AST6   [Do you / does person's name] still have asthma?

(Single Response)

1.   Yes
2.   No
3.   Don't know

COP3   Have you ever been told by a doctor that you have chronic bronchitis or emphysema?

(Single Response)

1.   Yes
2.   No
3.   Don't know

Sequence guide: If COP3 ≥ 2 go to CVD1

COP10   How old were you when you were first diagnosed with chronic bronchitis or emphysema?

(Single Response)

1.   Enter age   ____
2.   Don't know / refused

CVD1   Have you ever been told by a doctor that you have had any of the following conditions?

(Read Options. Multiple Response)

1.   **Heart attack**
2.   **Angina**
3.   **Heart disease**
4.   **Stroke**
5.   None of the above

Sequence guide: If CVD1 = 5 go to ART1

CVD10   How old were you when you were first diagnosed with [heart attack / angina / heart disease / stroke]?

(Single Response)

1.   Enter age   ____
2.   Don't know / refused

ART1   Have you ever been told by a doctor that you have arthritis?

(Read Options. Multiple Response.
Interviewer note: if yes, prompt **what type**?)

1. **Yes, Osteoarthritis**
2. **Yes, Rheumatoid Arthritis**
3. **Yes, Juvenile Rheumatoid Arthritis (JRA)**
4. **Yes, other (specify)**
5. No, don't have arthritis
6. Yes, don't know type

Sequence guide: If ART1=5 go to OST1

ART10   How old were you when you were first diagnosed with arthritis?

(Single Response)

1. Enter age   ____
2. Don't know / refused

OST1   Have you ever been told by a doctor that you have osteoporosis?

(Single Response)

1. Yes
2. No
3. Don't know

Sequence guide: If OST1 ≥ 2 AGE ≤16 go to COM1
       If OST1 ≥ 2 and AGE ≥ 16 Go to DIS1

OST10   How old were you when you were first diagnosed with osteoporosis?

(Single Response)

1. Enter age   ____
2. Don't know / refused

CAC1   [Have you / has child's name] ever been told by a doctor that [you have / he has / she has] cancer?

(Single Response)

3. Yes
4. No
5. Don't know/Refused

Sequence guide: If CAC1 >1 & AGE ≥ 16 Go to DIS1
 If CAC1 >1 &AGE < 16 Go to COM1

CAC2   What type of cancer was it?

(Multiple Response)

1. Gastrointestinal (colon (bowel)/ liver/ pancreatic/ stomach)
2. Leukemia/Lymphoma (lymph nodes and bone marrow)
3. Male cancers (prostate or testicular)

4. Skin melanoma
5. Skin non-melanoma (Squamous cell carcinoma / basal cell carcinoma)
6. Thoracic (heart/ lung)
7. Urinary (bladder/kidney)
8. Breast
9. Other Female (cervical/ uterus/ ovarian)
10. Head/Neck (head/ neck/ throat/ thyroid)
11. Brain
12. Other (specify)
13. Don't know / Not sure
14. Refused

CAC3   How old [were you / was your child] when first diagnosed with cancer?

(Single Response)

1. Enter age   ____
2. Don't know / refused

Sequence guide: If AGE ≥ 16 Go to DIS1

COM1   Does [child's name] have a long term illness or ongoing pain that puts pressure on you or the family as a whole?

(Single Response)

1. Yes
2. No
3. Don't know
4. Refused

Sequence guide: If AGE < 2 Go to NS

COM5   I am going to read you a list of problems or difficulties that some children have. Please tell me if a health care professional or other professional (e.g. teacher) has ever told you that [child's name] has:

(Read options. Multiple Response)

1. **Severe behavioural problems**
2. **Migraines and headaches**
3. **A problem with coordination and clumsiness**
4. **Developmental delay**
5. **Learning disorder or difficulty**
6. **Any other physical or intellectual disability**
7. **Attention Deficit Hyperactivity Disorder**
8. None of the above

Sequence guide: If AGE < 16 go to NS

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DIS1 These next questions are about disabilities, that is, physical, mental, or emotional problems or limitations you may have in your daily life.

Are you limited in any way in any activities because of any impairment or health problem?

(Single Response)

1. Yes
2. No
3. Don't know/not sure
4. Refused

Sequence guide: If AGE < 65 Go to NS

INJ1 Now I would like to ask you about falls that you may have had in the past year including those falls that did not result in injury as well as those that did.

How many falls (including slips, trips and falls to the ground) did you have in the past year?

(Single Response)

1. *Enter number of falls* _____
2. None
3. Don't know

Sequence guide: If INJ1 > 1 Go to NS

INJ2 Did you receive medical treatment for injuries from any of these falls or did you limit your usual activity for more than two days due to injuries from any of these falls?

(Single Response)

1. Medical treatment
2. Limit activity
3. Both
4. Neither

CARERS

Sequence guide: If age < 16 Go to NS

CAR1 Do you provide long- term care at home for a parent, partner, child, other relative or friend who has a disability, is frail, aged or who has a chronic mental or physical illness?

(Single Response Interviewer note: Long-term care is a minimum of 6 months and may extend into years)

1. Yes
2. No
3. Don't know
4. Refused

BLOOD PRESSURE (Risk Factors)

Sequence guide: If AGE < 16 Go to NS

HBP1 Have you ever been told by a doctor or a nurse that you have high blood pressure?

(Single Response. Interviewer note: do not include other health professional)

1. Yes
2. No
3. Don't know
4. Never measured

Sequence guide: If HBP1 = 4 Go to NS.

HBP3 When did you last have your blood pressure measured (by a doctor or nurse)?

(Single Response)

1. Less than 1 year ago
2. One to less than two years ago
3. Two to three years ago
4. More than 3 years ago
5. Never measured
6. Don't know

Sequence guide: If HBP3 = 5,6 Go to NS
If HBP1 ≥ 2 Go to NS.

HBP4 Do you still have high blood pressure?

(Single Response. Interviewer Note: Enter yes if controlled by tablets or medication)

1. Yes
2. No
3. Don't know

HBP5 Are you on tablets or other prescribed medication for blood pressure?

(Single Response)

1. Yes
2. No

CHOLESTEROL (Risk Factors)

Sequence guide: If AGE < 16 Go to NS

CHO1 Have you ever been told by a doctor or a nurse that you have high cholesterol?

(Single Response)

1. Yes
2. No
3. Don't know
4. Never measured

CHO2   **When did you last have your cholesterol measured (by a doctor or nurse)?**

(Single Response)

1. **Less than 1 year ago**
2. **One to less than two years ago**
3. **Two to three years ago**
4. **More than 3 years ago**
5. **Never measured**
6. **Don't know**

CHO3   **Do you still have high cholesterol?**

(Single Response. Interviewer Note: Enter yes if controlled by tablets or medication)

1. Yes
2. No
3. Don't know

CHO4   **Are you on tablets or other prescribed medication for high cholesterol?**

(Single Response)

1. Yes
2. No

PHYSICAL ACTIVITY (Protective Factors)

The next few questions are about physical activity.

PA20   **How many days in the past week, have you/[child] done any vigorous or moderate physical activity for a total of at least 60 minutes (this could be made up of different activities during the day like cycling or walking to and from school, playing sport at lunchtime or after school, doing an exercise class, doing household chores etc)?**

(Single Response)

1. None
2. Enter number of days _____
3. Unsure, Don't know, Can't remember
4. Refused

The next few questions are about any physical activities that you may have done in the last week. They are similar to the previous question but it would help our research if you could also answer these questions.

PA1   **In the last week, how many times have you walked continuously, for at least 10 minutes, for recreation, exercise or to get to or from places?**

(Single Response. Enter number of times. Enter 0 if none)

1. None   Go to PA7
2. *Enter number of times*   _____
3. Not stated/Don't know   [999]

PA2   **What do you estimate was the total time that you spent walking in this way in the last week?**

(Single Response. Enter number of hours AND/OR minutes)

1. *Hours*   _____
2. *Minutes*   _____
3. Not stated/Don't know   [999]

PA7   **This question excludes household chores or gardening. In the last week, how many times did [you /child] do any vigorous physical activity which made [you /child] breathe harder or puff and pant? (e.g. tennis, jogging, cycling, keep fit exercises).**

(Single Response. Enter number of times. Enter 0 if none)

1. None   Go to PA9
2. *Enter number of times*   _____
3. Not stated/Don't know   [999]

PA8   **What do you estimate was the total time that you spent doing this vigorous physical activity in the last week?**

(Single Response. Enter number of hours AND/OR minutes.)

1. *Hours*   _____
2. *Minutes*   _____
3. Not stated/Don't know   [999]

PA9   **This question excludes household chores or gardening.
In the last week, how many times did [you /child] do other more moderate physical activities that you have not already mentioned? (e.g. lawn bowls, golf, gentle swimming, etc)**

(Single Response. Enter number of times. Enter 0 if none)

1. None   Go to PA12
2. Enter number of times   _____
3. Not stated/Don't know   [999]

PA10 **What do you estimate was the total time that [you /child] spent doing these activities in the last week?**

(Single Response. Enter number of hours AND/OR minutes)

1. *Hours* ____
2. *Minutes* ____
3. Not stated/Don't know [999]

Sequence guide: If AGE ≥ 16 Go to NS

PA12 **On average, how many hours per day or per week does [child's name] spend doing organised sport?**

(Single Response. Interviewer note: Does not = PE at school, organised means regular commitment to activity. Enter number of hours/ day or hours/ week)

1. None [0]
2. *Enter hours per day* ____
3. *Enter hours per week* ____
4. Don't know [999]
5. Refused [998]

PA13 **On average how many hours per day or per week does [child's name] spend reading for pleasure?**

(Single Response. Interviewer note enter number of hours/ day or hours/ week)

1. None [0]
2. *Enter hours per day* ____
3. *Enter hours per week* ____
4. Don't know [999]
5. Refused [998]

PA21 **On an average school day, about how many hours a day does [child's name] spend doing HOMEWORK [when they are not at school]?**

(Single Response. Interviewer note: Enter number of hours/ day or hours/ week)

1. None [0]
2. Enter hours per day ____
3. Enter hours per week ____
4. Don't know [999]
5. Refused [998]

PA15 **On average how many hours per day or per week does [child's name] spend watching TV, videos or playing video or computer games?**

(Single Response. *Interviewer note enter number of hours/ day or hours/ week*)

1. None [0]
2. *Enter hours per day* ____
3. *Enter hours per week* ____

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4. Don't know [999]
5. Refused [998]

Sequence guide: If AGE ≥ 2 & < 5 Go to PA16

The following two questions are similar to the previous question. It would help our research if you could also answer these questions.

PA22 **On an average school day, about how many hours a day does [child's name] spend WATCHING TV/VIDEOS/DVDS [when they are not at school]?**

(Single Response. Interviewer note: Enter number of hours/ day or hours/ week)

1. None [0]
2. *Enter hours per day* ____
3. *Enter hours per week* ____
4. Don't know [99]
5. Refused [999]

PA23 **On an average school day, about how many hours a day does [child's name] spend USING THE INTERNET OR PLAY COMPUTER GAMES [when they are not at school]?**

(Single Response. Interviewer note: Enter number of hours/ day or hours/ week. Does not include computer use for homework.)

1. None [0]
2. Enter hours per day ____
3. Enter hours per week ____
4. Don't know [999]
5. Refused [998]

PA16 **On average how many hours per day or per week does [child's name] spend sleeping?**

(Single Response. Interviewer note enter number of hours/ day or hours/ week)

1. None [0]
2. *Enter hours per day* ____
3. *Enter hours per week* ____
4. Don't know [999]
5. Refused [998]

HEIGHT AND WEIGHT - BODY MASS INDEX (BMI) (Risk Factors)

BMI1 **What is [your / child's name] height without shoes?**

(Single Response)

1. *Centimetres* ___
OR
2. *Feet : Inches* ___ ___
3. Don't know
4. Refused

BMI3   Interviewer note: DO NOT READ. Has respondent measured height?

(Single Response)

1.   Yes
2.   No

BMI2   What is [your / child's name] weight? (Undressed in the morning)

(Single Response)

1.   *Kilograms (Kg)*   ___
OR
2.   *Stones : Pounds*   ___ ___
3.   Don't know
4.   Refused

BMI4   Interviewer note: DO NOT READ. Has respondent measured weight?

(Single Response)

1.   Yes
2.   No

Sequence guide: If AGE ≥ 16 Go to NS

BMI5   How much did you weigh a year ago?
[If female & age < 46: If you were pregnant a year ago, how much did you weigh before your pregnancy?]

(Single Response)

1.   *Kilograms (Kg)*   ___
OR
2.   *Stones : Pounds*   ___ ___
3.   Don't know / Not sure
4.   Refused

Interviewer note: Subtract weight one year ago from current weight. If weight is same, Go to NS.

BMI6   Was the change between your current weight and your weight a year ago intentional?

(Single Response)

1.   Yes
2.   No
3.   Don't know / Not sure
4.   Refused
5.   No change

SMOKING (Risk Factors)

Sequence guide: If AGE < 16 Go to SMO6 (skip introduction)

The following questions are about tobacco smoking. This includes cigarettes, cigars and pipes.

SMO6   Which of the following best describes your home situation?

(Read options. Single Response)

1.   **My home is smoke free** (includes smoking is allowed outside)
2.   **People occasionally smoke in the house**
3.   **People frequently smoke in the house**
4.   Don't know
5.   Refused

Sequence guide: If AGE < 16 Go to NS

SMO1   Which of the following best describes your smoking status?

(Read options. Single Response)

1.   **I smoke daily**
2.   **I smoke occasionally**
3.   **I don't smoke now but I used to**
4.   **I've tried it a few times but never smoked regularly**
5.   **I've never smoked**
6.   Refused

Sequence guide:
If SMO1 = 3 (Ex-smoker) go to SMO7
If SMO1 = 4, 5,6 (non-smoker) go to NS

SMO3   On average how many cigarettes do you smoke per day or each week?

(Single Response. Enter number)

1.   *Daily*   ___
2.   *Weekly*   ___
3.   *Monthly*   ___
4.   Don't know

Sequence guide: Go to NS

SMO7   Over your lifetime would you have smoked at least 100 cigarettes or similar amount of tobacco?

(Single Response)

1.   Yes
2.   No
3.   Don't know
4.   Refused

ALCOHOL CONSUMPTION (Risk Factors)

Sequence guide: If AGE < 16 Go to NS

The following questions are about drinking alcohol.

ALC1   How often do you usually drink alcohol?

(Single Response)

1.   I don't drink alcohol   Go to NS
2.   Less than once a week
3.   *Specify number of days per week* ___
4.   Refused   Go to NS

ALC2   A Standard Drink is equivalent to a schooner or midi of full strength beer, a glass of wine or a nip of spirits. On a day when you drink alcohol, how many drinks do you usually have?

(Single Response)

1.   *Specify number drinks*   ___
2.   Refused

NUTRITION - Food Consumption (Protective Factors)

Sequence guide: If AGE < 1 Go to NS

Now to some questions about food. The following question is about eating vegetables which includes fresh, dried, frozen and tinned vegetables.

NUT1   How many serves of vegetables [do you / does child's name] usually eat each day? A 'serve' is ½ cup cooked vegetables or 1 cup of salad.

(Single Response)

1.   Less than one serve
2.   *Enter number of serves*   ___
3.   Don't eat vegetables
4.   None
5.   Don't know

The next question is about eating fruit, which includes fresh, dried, frozen and tinned fruit.

NUT2   How many serves of fruit [do you / does child's name] usually eat each day? A 'serve' is 1 medium piece or 2 small pieces of fruit or 1 cup of diced pieces, or 1 tablespoon of dried fruit.

(Single Response)

1.   Less than one serve
2.   *Enter number of serves*   ___
3.   Don't eat fruit
4.   None
5.   Don't know

NUT3   What type of milk do you [do you/ does child's name] usually have?

(Single Response Interview note: If brand of milk given, prompt for type, ie whole milk or reduced fat)

1.   Whole milk
2.   Low or reduced fat
3.   Skim
4.   Soya
5.   Evaporated/ sweetened condensed
6.   Other (specify)
7.   None of the above
8.   Don't know
9.   High calcium, low fat
10. Breast milk
11. Formula
12. Rice milk
13. Doesn't drink milk

NUT4   How often do [do you/does child's name] you eat chips, french fries, wedges, fried potatoes or crisps?

(Single Response. Interview note: enter number of times per day, week or month)

1.   *Enter number of times per day*   ____
2.   *Enter number of times per week*   ____
3.   *Enter number of times per month* ____
4.   Rarely (< once / month)
5.   Never
6.   Don't know/can't say

NUT8   How often [do you/does child's name] eat meat products such as sausages, frankfurters, devon (fritz), salami, meat pies, bacon or ham?

(Single Response. Interview note: enter number of times per day, week or month)

1.   *Enter number of times per day*   ____
2.   *Enter number of times per week*   ____
3.   *Enter number of times per month* ____
4.   Rarely (< once / month)
5.   Never
6.   Don't know/can't say

NUT17 How many times a week on average [do you/ does child's name] have meals or snacks such as burgers, pizza, chicken or chips from places like McDonalds, Hungry Jacks, Pizza Hut or Red Rooster?

(Single Response. Interview note: enter number of times per day, week or month)

1. *Enter number of times per day* ____
2. *Enter number of times per week* ____
3. *Enter number of times per month* ____
4. Rarely
5. Never
6. Don't know/can't say

NUT18 During the last four weeks, on average, how many glasses of water [do you / does child's name] usually have in a day?

(Single Response. Interviewer note: water is tap, bottled, rain. This does not include fruit juice, cordial, fizzy or energy drinks, milk, tea or coffee. A glass = 200 mls)

1. *Enter number of glasses* ____
2. *Enter mls* ____
3. *Enter litres* ____
4. None
5. Don't know

NUT46 How many cups of fruit or vegetable juice [do you / does child's name] usually drink each day? This does not include fruit juice drinks and fruit drinks (eg Fruitbox).

(Single Response. Interviewer note: 1 cup = 250 mls)

1. *Enter cups*
2. *Enter litres*
3. Don't know
4. Refused

NUT47 On average, how many litres of soft drink (eg coke, lemonade, flavoured mineral water,) [do you / does child's name] usually have in a day?

(Single Response)

1. Enter ____
2. Don't know
3. Refused

NUT50 On average, how many cups or litres of sports drink (eg Powerade, Gatorade) [do you / does child's name] usually have in a day?

(Single Response. Interviewer note: 1 cup=250mls)

1. Enter MLS ____
2. Enter litres ____
3. Don't know
4. Refused

NUTRITION – Folate   (Protective Factors)

Sequence guide: If AGE < 16 go to NS

NUT24 Do you know when folic acid needs to be taken by a woman to reduce her chance of having a baby with spina bifida?

(Read options. Single Response)

~~1.~~
2. **Before pregnancy**
3. **Before pregnancy and in first three months of pregnancy**
4. **In first three months of pregnancy only**
5. **In the first six months of pregnancy**
6. **Throughout pregnancy**
7. Before pregnancy and throughout pregnancy
8. Other (specify)
9. Not sure Don't know

Sequence guide: If (SEX=1) OR ((AGE < 16 or ≥ 50) & SEX = 2) Go to NUT43
If NUT41 = 1, 3 or 4 go to NUT27
If NUT41 =Go to NUT26.
Else Go to NUT43

The following question is similar to one we asked you earlier about babies you have given birth to.

NUT26 Can you please tell me if you have given birth in the last three years?

(Single Response. Interviewer note: If more than one birth, most recent only.)

1. Yes, *specify year* ____
2. No

NUT27 Can you tell me if you are currently pregnant?

(Single Response. Interviewer note: Enter number of months or weeks)

1. Yes, *specify weeks* ____
2. Yes, *specify months* ____
3. No

Sequence guide: If NUT26 = 2 & NUT27 = 3 Go to NUT43

NUT28 In the month before you became pregnant the last time, did you do any of the following?

(Read options. Multiple Response)

1. **Took folic acid tablets every day**
2. **Ate cereals or other prepared foods/juices specially enriched with folic acid every day**
3. **Increased your intake of foods rich in folate or folic acid, such as green leafy vegetables, cereals and fruits**
4. None
5. Not sure

NUT29 In the first three months of your current or most recent pregnancy, did you do any of the following?

(Read options. Multiple Response)

1. **Took folic acid tablets every day**
2. **Ate cereals or other prepared foods/juices specially enriched with folic acid every day**
3. **Increased your intake of foods rich in folate or folic acid, such as green leafy vegetables, cereals and fruits**
4. None
5. Not sure

FOOD SECURITY (Social Factor)

Changing the subject for a moment to some more questions about food.

NUT43 In the last twelve months, were there any times that you ran out of food and you couldn't afford to buy more?

(Single Response)

1. Yes
2. No
3. Don't know
4. Refused

Sequence guide: If NUT31 > 1 Go to NS

NUT32 How often did this happen?

(Single Response. Interviewer note: enter number of times per day, week or month)

1. *Enter number of times per week* ___
2. *Enter number of times per fortnight*___
3. *Enter number of times per month* ___
4. *Enter number of times per year* ___
5. Rarely
6. Never
7. Don't know/ can't say

CHILDCARE

Sequence guide: If AGE > 5 Go to NS

Now some questions about the use of childcare

CHC4 In total, how many hours per week is [child's name] usually cared for in <u>formal</u> childcare?

(Single Response)

1. *Hours per week* ____
2. None
3. Don't know
4. Refused

EARLY YEARS

Sequence guide: If AGE ≥ 16 Go to NS

Now we would like to ask some questions about [*child's name*] development.

CHD1 A premature birth or a 'pre-term' birth is one that occurs at less than 37 weeks gestation. Was [child's name] born prematurely?

(Single Response)

1. Yes
2. No
3. Don't know
4. Refused

SCHOOL PERFORMANCE

Sequence guide: If AGE < 5 & ≥ 16 Go to NS

SCH1 Thinking about the previous month, can you tell me about how many days (other than holidays) [child's name] has been away from school for any reason?

(Single Response)

1. None [0]
2. *Enter number of days* ____
3. Doesn't go to school
4. Don't know [999]
5. Refused [9999]

Sequence guide: If SCH1 = 3 Go to NS

SCH4   Is [child's name] ever unhappy at school?

(Read options. Single Response)

1. **Never**
2. **Rarely**
3. **Sometimes**
4. **Often**
5. **Always**
6. Not applicable
7. Don't know
8. Refused

SCH5   Does [child's name] have a special friend or a really close mate?

(Single Response)

1. Yes
2. No
3. Don't know
4. Refused

SCH6   Does [child's name] have a group of friends to play with or hang around with?

(Single Response)

1. Yes
2. No
3. Don't know
4. Refused

Sequence guide: If AGE > 12 Go to SCH9

SCH7   Do you use after school or vocational care?

(Single Response)

1. Yes
2. No
3. Never needed care
4. Don't know
5. Refused

SCH9   The next questions are about bullying at school. Bullying is when someone is picked on, hit, kicked, threatened, actively excluded or ignored by other children.

In the last month, has [child's name] been bullied?

(Single Response)

1. Yes
2. No
3. Don't know
4. Refused

Sequence guide: If SCH9 > 1 Go to NS

SCH10   Was the bullying emotional or physical?

(Single Response)

1. Emotional
2. Physical
3. Both
4. Don't know
5. Refused

SCH9B   Bullying can also include cyber bullying, using text messages or racial/cultural insults. In the last month, has [child's name] been bullied in this way?

(Single Response)

1. Yes
2. No
3. Don't know
4. Refused

MENTAL HEALTH

Now some questions about concentration and behaviour

Sequence guide: If AGE < 2 AND ≥ 16 Go to NS

MTL16   Overall, does [child's name] have trouble with emotions, concentration, behaviour or getting on with people? Would you say

(Read options. Single Response)

1. **No**
2. **Only a little**
3. **Quite a lot**
4. **Very much**
5. Don't know / refused

Sequence guide: If MTL16 = 1 Go to MTL18

MTL17   Do you think [child's name] needs special help for this?

(Single Response)

1. Yes
2. No
3. Don't know
4. Refused

MTL18   Has [child's name] ever been <u>treated</u> for an emotional, mental health or behavioural problem?

(Single Response)

1. Yes
2. No
3. Don't know
4. Refused

Sequence guide: If MTL18 > 1 Go to NS

MTL19   Who has treated [child's name]?

(Multiple Response)

1. School counsellor
2. Psychologist
3. Youth worker
4. Social worker
5. Psychiatrist
6. Other (specify)
7. Don't know
8. Paediatrician
9. GP
10. Neurologist
11. CAM practitioner
12. C&YH

KESSLER PSYCHOLOGICAL DISTRESS SCALE+ (K10+) (Health Status)

Sequence guide: If AGE < 16 Go to NS

The next questions are about how you have been feeling in the last 4 weeks.

MTL1   In the past four weeks, about how often did you feel tired out for no good reason?

(Read Options. Single Response)

1. **All of the time**
2. **Most of the time**
3. **Some of the time**
4. **A little of the time**
5. **None of the time**
6. Don't know
7. Refused

MTL2   In the past four weeks, about how often did you feel nervous?

(Read Options. Single Response)

1. **All of the time**
2. **Most of the time**
3. **Some of the time**
4. **A little of the time**
5. **None of the time**
6. Don't know
7. Refused

Sequence guide: If MTL2 = 5 Go to MTL4

MTL3   In the past four weeks, about how often did you feel so nervous that nothing could calm you down?

(Read Options. Single Response)

1. **All of the time**
2. **Most of the time**
3. **Some of the time**
4. **A little of the time**
5. **None of the time**
6. Don't know
7. Refused

MTL4   In the past four weeks, about how often did you feel hopeless?

(Read Options. Single Response)

1. **All of the time**
2. **Most of the time**
3. **Some of the time**
4. **A little of the time**
5. **None of the time**
6. Don't know
7. Refused

MTL5   In the past four weeks, about how often did you feel restless or fidgety?

(Read Options. Single Response)

1. **All of the time**
2. **Most of the time**
3. **Some of the time**
4. **A little of the time**
5. **None of the time**
6. Don't know
7. Refused

Sequence guide: If MTL5 = 5 Go to MTL7

MTL6   In the past four weeks, about how often did you feel so restless you could not sit still?

(Read Options. Single Response)

1. **All of the time**
2. **Most of the time**
3. **Some of the time**
4. **A little of the time**
5. **None of the time**
6. Don't know
7. Refused

MTL7   In the past four weeks, about how often did you feel depressed?

(Read Options. Single Response)

1. **All of the time**
2. **Most of the time**
3. **Some of the time**
4. **A little of the time**
5. **None of the time**
6. Don't know
7. Refused

MTL8   In the past four weeks, about how often did you feel everything was an effort?

(Read Options. Single Response)

1. **All of the time**
2. **Most of the time**
3. **Some of the time**
4. **A little of the time**
5. **None of the time**
6. Don't know
7. Refused

MTL9   In the past four weeks, about how often did you feel so sad that nothing could cheer you up?

(Read Options. Single Response)

1. **All of the time**
2. **Most of the time**
3. **Some of the time**
4. **A little of the time**
5. **None of the time**
6. Don't know
7. Refused

MTL10   In the past four weeks, about how often did you feel worthless?

(Read Options. Single Response)

1. **All of the time**
2. **Most of the time**
3. **Some of the time**
4. **A little of the time**
5. **None of the time**
6. Don't know
7. Refused

SUICIDAL IDEATION (Health Status)

Sequence guide: If AGE < 16 Go to NS

MTL11   Over the past few weeks, have you felt that life isn't worth living?

(Read Options. Single Response)

1. **Not at all**
2. **No more than usual**
3. **Rather more than usual**
4. **Much more than usual**
5. Don't know
6. Refused

MTL12   [Over the past few weeks] Have you thought of the possibility that you might do away with yourself?

(Read Options. Single Response)

1. **Definitely not**
2. **I don't think so**
3. **Has crossed my mind**
4. **Definitely have**
5. Don't know
6. Refused

MTL13   [Over the past few weeks] Have you found yourself wishing you were dead and away from it all?

(Read Options. Single Response)

1. **Not at all**
2. **No more than usual**
3. **Rather more than usual**
4. **Much more than usual**
5. Don't know
6. Refused

MTL14   [Over the past few weeks] Have you found that the idea of taking your own life kept coming into your mind?

(Read Options. Single Response)

1. **Definitely not**
2. **I don't think so**
3. **Has crossed my mind**
4. **Definitely have**
5. Don't know
6. Refused

MENTAL HEALTH (Health Status)

Sequence guide: If AGE < 16 Go to NS

MTL20   In the last 12 months have you been told by a doctor that you have any of the following conditions?

(Read Options. Multiple Response)

1. **Anxiety**
2. **Depression**
3. **A stress related problem**
4. **Any other mental health problem**
5. None   Go to MTL22
6. Refused   Go to MTL22

MTL21   Do you still have [this / any of these] condition(s)?

(Single Response)

1. Yes
2. No
3. Refused

MTL22   Are you currently receiving treatment for anxiety, depression, stress related problems or any other mental health problem?

(Single Response. Interviewer note: includes phone treatment)

1. Yes
2. No
3. Refused

MTL27   In the last 12 months were you FIRST told by a doctor that you either have anxiety, depression, a stress related problem or any other mental health problem?

(Single Response)

1. Yes
2. No
3. Don't know
4. Refused

SOCIAL CAPITAL (Social Factor)

Now some general questions about <u>your neighbourhood</u>.

SOC2   Overall, do you feel that your neighbourhood is a safe place?

(Single response)

1. Yes
2. No
3. Don't know / not sure

SOC3   Do you think that in this neighbourhood people generally trust one another?

(Single response)

1. Yes
2. No
3. Don't know / not sure

SOC4   Do you feel safe in your home?

(Read Options. Single response)

1. **All of the time**
2. **Most of the time**
3. **Some of the time**
4. **None of the time**
5. Don't know

Sequence guide: If AGE < 16 Go to SOC8

SOC5   Do you agree or disagree with the following statement?

I have control over the decisions that affect my life.

(Read Options. Single response)

1. **Strongly agree**
2. **Agree**
3. Neutral/don't know
4. **Disagree**
5. **Strongly disagree**

SOC8   How often do you have problems with transport when you want to go, for example, to hospital, medical appointments, recreational facilities, visiting people, shopping, school or childcare?

(Read options. Single Response)

1. **Never**
2. **Sometimes**
3. **All the time**
4. Don't know

ECONOMICS

Sequence guide: If AGE < 16 Go to NS

ECO1   Beginning yesterday, and going back 4 weeks, how many days out of the past 4 weeks were you totally unable to work or carry out your normal duties because of your health?

(Single Response. Enter number of days off. Enter 999 if unknown)

1. None   [0]
2. *Enter days*   _____
3. Don't know   [999]

ECO2 **[Apart from (that day/these days)] how many days in the past 4 weeks were you able to work and carry out your activities, but had to cut down what you did, or did not get as much done as usual because of your health?**

(Single Response. Enter number of days off. Enter 999 if unknown)

1. None   [0]
2. *Enter days*   _____
3. Don't know   [999]

LIFE COURSE

Sequence guide: If AGE < 16 Go to NS

The following questions are about you and your family's situation when you were 10 years old.

DEM40 How would you best describe your family structure when you were 10 years old?

(Read options. Single response)

1. **Family with child/children living with both biological or adoptive parents**
2. **A step or blended family**
3. **A sole parent family (lived only with mother)**
4. **A sole parent family (lived only with father)**
5. **Shared care parenting**
6. **Lived with relatives/grandparents**
7. **Boarded/ orphanage/ children's home/ foster care/ other**
8. Other (specify)
9. Don't know
10. Refused

DEM41 When you were 10 years old, was the dwelling you were living in…

(Read options. Single response. Interviewer note: prompt if rent free, prompt if dwelling rented or owned)

1. **Owned or being purchased**
2. **Rented from the housing trust or government**
3. **Rented privately**
4. **Provided with employment**
5. Other (specify)
6. Don't know
7. Refused

DEM42 Which best described your family's money situation when you were 10 years old?

(Read options. Single response)

1. **We spent more money than we got**
2. **We had just enough money to get through to the next pay**
3. **Some money left over each week but we just spent it**
4. **We could save a bit every now and then**
5. **We could save a lot**
6. Other (specify)
7. Don't know
8. Refused

SOCIAL CHARACTERISTICS

Now to finish off with some general questions.

DEM8   What is the Postcode of the house?

(Single Response)

1. *Enter postcode*   ____
2. Not stated   [9999]

Sequence Guide: If DEM8 < 9999 Go to DEM10

DEM9   What town, suburb or community do you live in?

(Single Response.)

1. *Enter town/suburb*   ____
2. Not stated

DEM10   How would you best describe your family structure? Please listen to the descriptions and then tell me which one is the closest to your family situation.

(Read options. Single Response. Interviewer note: only read out appropriate categories)

1. **A family with a child or children living with both biological or adoptive parents**
2. **A step or blended family**
3. **A sole parent family**
4. **Shared care parenting**
5. **Adult living alone**
6. **Adult living with partner and no children**
7. **Related adults living together**
8. **Unrelated adults living together**
9. **Other** (specify)
10. Refused

Sequence guide: If AGE ≥ 16 Go to DEM12
          If DEM10 = 1 or >4 Go to DEM12

DEM12 **Which of these best describes your current employment status? Are you**

(Read Options. Single Response)

1. **Self employed**
2. **Employed for wages, salary or payment in kind**
3. **Unemployed**
4. **Engaged in home duties**
5. **Student**
6. **Retired**
7. **Unable to work**
8. Other (Specify)

Sequence guide: If AGE $\geq$ 16 & DEM12 > 2 Go DEM16
    If DEM12 > 2 & DEM10 > 2 Go to DEM16
    If DEM12 > 2 & DEM10 $\leq$ 2 Go to DEM14

DEM13 **How many hours do you work per week?**

(Single Response)

1. *Enter number of hours per week* _____
2. Don't know

Sequence guide: If AGE $\geq$ 16 Go to DEM16
    If DEM10 > 2 Go to DEM16

DEM14 **Now some questions about the other partner in the household.**

Which of these best describes the other partner's current employment status? Are they…?

(Read Options. Single Response)

1. **Self employed**
2. **Employed for wages, salary or payment in kind**
3. **Unemployed**
4. **Engaged in home duties**
5. **Student**
6. **Retired**
7. **Unable to work**
8. Other (Specify)
9. Not stated/ Don't know

Sequence guide: If DEM14 > 2 Go to DEM16

DEM15 **How many hours do they work per week?**

(Single Response)

1. *Enter number of hours per week* _____
2. Don't know

DEM16 **In which country [were you / was child's name] born?**

(Single Response)

1. Australia
2. Austria
3. Bosnia-Herzegovina
4. Canada
5. China
6. Croatia
7. France
8. Germany
9. Greece
10. Holland / Netherlands
11. Hong Kong
12. Iran
13. Italy
14. Japan
15. Malaysia
16. New Zealand
17. Philippines
18. Poland
19. Slovenia
20. Spain
21. U.K. and Ireland
22. USA
23. Vietnam
24. Former Yugoslav Republic of Macedonia
25. Former Yugoslav Republics of Serbia & Montenegro
26. Other country (specify)
27. Refused
28. Fiji
29. India
30. South Africa]

Sequence guide: If DEM16 > 1 Go to DEM18

DEM17 **[Are you / is child's name] of Aboriginal or Torres Strait Islander origin?**

(Single Response)

1. No
2. Aboriginal
3. Torres Strait Islander
4. Both
5. Not stated

Sequence guide: if AGE < 16 Go to DEM20

DEM18 **[Do you / does child's name] speak a language, other than English, at home?**

(Single Response)

1. Yes
2. No
3. Not stated

DEM19   What is your current marital status?

(Read Options. Single Response)

1. **Married**
2. **Living with a partner** (De Facto)
3. **Divorced**
4. **Separated**
5. **Widowed**
6. **Never Married**
7. Not stated

DEM20   What is the highest level of education you have completed?

(Single Response. Interviewer note: Prompt if necessary)

1. Never attended school
2. Some primary school
3. Completed primary school
4. Some high school
5. Completed high school (i.e. Year 12, Form 6, HSC)
6. TAFE or trade certificate or diploma
7. University, CAE or some other tertiary institute degree
8. Other (specify)

Sequence guide: If AGE ≥ 16 Go to DEM22
        If DEM10 > 2 Go to DEM22

DEM21   What is the highest level of education the other partner in the house has completed?

(Single Response. Interviewer note: Prompt if necessary)

1. Never attended school
2. Some Primary school
3. Completed Primary School
4. Some High School
5. Completed High School (i.e. Year 12, Form 6, HSC)
6. TAFE or Trade Certificate or Diploma
7. University, CAE or some other Tertiary Institute degree
8. Other (specify)
9. Not stated

DEM22   The next question is about housing. Is this dwelling …

(Read Options. Single Response)

1. **Owned or being purchased**
2. **Rented from Housing SA**
3. **Rented privately**
4. Other (specify)
5. Community Housing
6. Retirement Village
7. Don't know
8. Refused

DEM23   Which best describe your family's money situation?

(Read Options. Single Response)

1. **[I am / we are] spending more money than [I / we] get**
2. **[I / we] have just enough money to get [me / us] through to the next pay day**
3. **There's some money left over each week but [I / we] just spend it**
4. **[I / we] can save a bit every now and then**
5. **[I / we] can save a lot**
6. Don't know
7. Refused

DEM24   Can you tell me the approximate annual gross income of your household? That is, for all people in the household before tax is taken out. I'll read out some categories and could you please tell me into which one your household's income falls?

(Read Options. Single Response)

1. **Up to $12,000**
2. **$12,001 - $20,000**
3. **$20,001 - $40,000**
4. **$40,001 - $60,000**
5. **$60,001 - $80,000**
6. **$80,001 - $100,000**
7. **More than $100,000**
8. Not stated/refused
9. Don't know

PHO1   How many residential telephone numbers, including mobile phones, can be used to speak to someone in this household?

(Single Response. Interviewer note: do not include Internet or fax numbers)

1. *Enter number*   __
2. Don't know   [99]

PHO2   How many times [do these / does this] number(s) appear in the White Pages?

(Single Response. Interviewer note: do not include Internet or fax numbers. Total number of entries includes numbers that are listed more than once.)

1. *Enter number*   __
2. Don't know   [99]

DEM25 **All responses in this survey are strictly confidential. Sometimes we need to clarify issues which require further explanation or to gather extra information about you [or about the children in your household] when there is a serious public health problem. If we require further information from you regarding health issues, could we phone you at a later date for help?**

(Single Response)

1. Yes (specify - record first name of respondent, not parent or guardian only)
   _____
2. No

Sequence guide: If DEM25 =2, go to NS.

GEOCODING

A new development in health information is the mapping of various conditions and risk factors, that gives an overall picture of the health of South Australians. The mapping points are within 200 metres from a starting position, and for this we need your home address. We stress that this information is kept strictly confidential.

182b. Would you like to help us with this?

(Single Response. Interviewer note: suggest respondent uses a tape measure for height. If the respondent does not have a tape measure for height and/or scales for weighting, suggest borrowing this/these from family, neighbours, friends, Child & Youth Services local offices, chemist, local doctor's surgery)

1. Yes
2. No   Skip the next question

182 DEM34 Can I please confirm your address is *…(address supplied on screen for <u>interviewer to read</u>)*

(Single Response)

1. Yes (address conf)
2. Different address (specify)
3. Refused

As some of the questions we have asked may have been distressing or caused some concern for some people, I would like to offer you a telephone number if you feel that you need to discuss some of these concerns with a qualified professional.

[Adult Mental Health Services – 24 hour crisis and emergency assistance – 131-465]

PHO3   Did the respondent accept the number?

(Single Response)

1. Yes
2. No

173B If you have any queries regarding this survey or would like to speak to someone at SA Health please telephone 1800 635 352

DEM26   Please record what language this interview was conducted in

(Single Response)

1. English
2. Italian
3. Greek
4. Vietnamese
5. Other (specify)

PH99   Interviewer note: Please record type of phone number respondent was contacted on to complete the survey. Note this may not necessarily be the phone number on screen.

(Single Response)

1. Landline
2. Mobile

PH04   Do you have a (landline) telephone connected to this house (not including mobile phones)?

(Single Response. Interviewer note: do not include internet or fax number)

1. Yes
2. No
3. Don't know
4. Refused

PH05   [Interviewer note: if you have already established the answer to this question, please code appropriately]. Are there any mobile phones currently being used by members of this household (including work phones)?

(Single Response. Interviewer note: do not include internet or fax number)

1. Yes
2. No
3. Don't know
4. Refused

That concludes the survey. On behalf of the SA Dept of Health, thank you very much for taking part in this survey. NOTE: if callingback for child measurements please say 'we will call you in a week's time'.

APPENDIX 2: HEALTH OMNIBUS SURVEY (HOS) QUESTIONS 2006 TO 2013

Telephone questions by survey year

	Survey year							
	2006	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**
Q1	Do you have a telephone connected to this house (<u>not</u> including mobile phones)? 1 Yes (Go to Q3) 2 No				Do you have a telephone landline connected to this house (this does not include mobile phones or VOIP)? [1] 1 Yes 2 No 3 Refused		Do you have a telephone landline connected to this house (this does not include mobile phones or VOIP)?[2] 1 Yes 2 No 3 Refused	
Q2					Does your household have VOIP connected to make telephone calls? (Includes Naked DSL) If no landline or VOIP (2 in Q1 and 2 in Q2) Go to Q4 1 Yes 3 Don't know 2 No 4 Refused			
Q3	Is this telephone number listed in the white pages as a residential (ie ordinary) number? *(if more than one telephone, ask about main telephone or one used most)* 1 Yes 2 No		1 Yes 3 Don't know 2 No 4 Refused		*If no landline or VOIP (2 in Q1 **and** 2 in Q2) Go to Q4* **Is the telephone landline and/or VOIP number listed in the white pages as a residential (ie ordinary) number?** 1 Yes, both 4 No 2 Yes, telephone only 5 Don't know 3 Yes, VOIP only 6 Refused			
Q4	How many mobile phones are currently being used by members of this household?	How many mobile phones are currently being used by members of this household? (Includes work phone) 1 Enter number (If none record '0' and go to Next Section 2 Don't know (D) 999 refused 997 not stated 3 Refused (R) 998 don't know						
Q5	Are you the primary user of one of these mobile phones? 1 Yes 3 Don't know 2 No (Go to Next section) 4 Refused 5 Not stated							
Q6	Is your mobile number listed in the white pages?	Is your mobile number listed in the white pages? (includes work phone) 1 Yes 3 Don't know 2 No 4 Refused						

1 Interviewer note: Voice over Internet Protocol (VoIP) is a general term for a family of transmission technologies to allow voice communications over IP networks such as the Internet. VoIP requires a normal phone, analog telephone adapte (ATA) device (box) and broadband internet connection, and is not dependent on the computer

2 Interviewer note: Voice over Internet Protocol (VoIP) is a general term for a family of transmission technologies to allow voice communications over IP networks such as the Internet. VoIP requires a normal phone, analog telephone adapte (ATA) device (box) and broadband internet connection, and is not dependent on the computer) this does not include Skype.

DEMOGRAPHIC VARIABLES

Q1. As some questions are asked only of people in particular age categories may I commence by asking your age?

(Single response)

1. *Enter age*   __

Q2. *Interviewer*

(Single response)

1. Male
2. Female

Q3. Including yourself, how many people aged 15 or over are there in the household?

(Single response)

1. *Enter number*   __

Z1 In which country were you born?

(Single response)

1. Australia   go to Z.2
2. UK and Ireland
3. Italy
4. Greece
5. Holland
6. Germany
7. Other European
8. New Zealand
9. African Country
10. Asian Country
11. South America
12. North America
13. Oceania
14. Other (specify)

Sequence Guide   If Z1 = 1 Go to Z3

Z.2 Are you of Aboriginal or Torres Strait Islander origin?

(Single response)

1. No
2. Aboriginal
3. Torres Strait Islander
4. Both
5. Don't know

Z.3 What is your marital status?

(Single response. Read options)

1. Married
2. De facto
3. Separated/divorced
4. Widowed
5. Never married

Z4 Which of these best describes your household?

(Single response. Show prompt card)

1. **A family with a child or children with both biological or adoptive parents**
2. **A step or blended family**
3. **A sole parent family**
4. **Shared care parenting**
5. **Adult living alone**
6. **Adult living with partner and no children**
7. **Related adults living together**
8. **Unrelated adults living together**
9. Other
10. Refused

Z.5 Which of these groups best describes the highest qualification you have obtained?

(Single response. Show Prompt Card)

1. **Still at school**   go to Z.7
2. **Left school at 15 years or less**
3. **Left school after age 15**
4. **Left school after age 15 but still studying**
5. **Trade qualification/ apprenticeship**
6. **Certificate/Diploma – one year full time or less**
7. **Certificate/Diploma – more than one year full time**
8. **Bachelor degree or higher**

Z.6 What kind of work have you done for most of your life?

(Single response. Interviewer: Please specify fully eg if response is Clerk, ask What type of Clerk)

……………………………………
……………………………………

Z.7 Which of these I shall read out best describes what you do?

(Single response)

1. **Work full time**
2. **Work part time**
3. **Home duties**
4. **Unemployed**
5. **Retired**
6. **Student**
7. **Not working because of work related injury**
8. **Not working because of disability**
9. Other

Z.7 The next question is about housing. Is this dwelling..?

(Single response)

1. Owned or being purchased
2. Rented from Housing SA
3. Rented privately
4. Community Housing
5. Retirement Village
6. Other (specify)
7. Don't know
8. Refused

I would now like to ask you about your household's income. We are interested in how income relates to lifestyle and access to health services.

Z10 Before tax is taken out, which of the following ranges best describes your household's income, from all sources, over the last 12 months?

(Single response. Show Prompt Card)

1. Up to $12,000
2. $12,001 - $20,000
3. $20,001 - $30,000
4. $30,001 - $40,000
5. $40,001 - $50,000
6. $50,001 - $60,000
7. $60,001 - $80,000
8. $80,001 - $100,000
9. $100,001 - $120,000
10. $120,001 - $140,000
11. $140,001 - $160,000
12. $160,001 - $180,000
13. $180,001 or more
14. Not stated

[2011, 2012, 2013 HOS]

Z.11 What is your postcode?

(Single response)

1. *Enter postcode* __

HEALTH RELATED VARIABLES
Physical activity

Asthma

B.1 Have you ever been told by a doctor that you have asthma?

(Single response)

1. Yes
2. No   go to next section
3. Don't know   go to next section

[2010, 2011 HOS]

B.3 Do you still have asthma?

(Single response)

1. Yes
2. No
3. Don't know

[2010, 2011 HOS]

Diabetes

C.1 Have you been told by a doctor that you have diabetes?

(Single response)

1. Yes
2. No
3. Don't know

[2010, 2011, 2013 HOS]

Osteoporosis

C.3 Have you been told by a doctor that you have osteoporosis (that is osteoporosis not osteoarthritis)?

(Single response)

1. Yes
2. No

[2013 HOS]

Arthritis

C.6 Have you been told by a doctor that you have arthritis? If yes, **What type?**

(Multiple response)

1. Osteoarthritis
2. Rheumatoid arthritis
3. Yes, but don't know what type
4. Yes, Other (specify)
5. No, don't have arthritis
6. Don't know
7. Refused

[2010, 2011, 2012, 2013]

Mental health condition

N1 Are you currently receiving treatment for anxiety, depression, or any other mental health problem?

(Single response)

1. Yes
2. No

[2010, 2011, 2012, 2013 HOS]

N2 Are you currently receiving the disability pension on the basis of a psychological or psychiatric illness?

(Single response)

1. Yes
2. No

[2010, 2011, 2012, 2013 HOS]

Smoking status

H1 Do you currently smoke cigarettes, cigars, pipes or any other tobacco products:

(Single response)

1. Daily
2. At least weekly (not daily)
3. Less often than weekly
4. Not at all   Go to Next Section

[2010, 2011, 2012, 2013 HOS]

H1 Over your lifetime would you have smoked at least 100 cigarettes or a similar amount of tobacco?

(Single response)

1. Yes
2. No

[2010, 2011, 2012, 2013 HOS]

Body mass index

Z1 What is your height without shoes?

(Single Response)

1. centimetres   _____
2. feet: inches   ____ ____
3. don't know   [999]

[2010, 2011, 2012, 2013 HOS]

Z2 What is your weight? (Undressed in the morning)

(Single Response)

1. kilograms (kg)   _____
2. stones: pounds   ____ ____
3. don't know   [999]

[2010, 2011, 2012, 2013 HOS]

APPENDIX 3: SAMSS AND CENSUS DEMOGRAPHIC COMPARISONS FOR RAKED WEIGHTS

The section will outline the population control margins used in the raking process and how they compare to the questions asked in SAMSS.

Age, sex and area of residence

Population surveys generally have lower participation from young people and males. This is evident in Table 3 A where the 2011 SAMSS sample is compared to the South Australian 2011 Census figures. These variables will be considered as essential margin variables for raking.

Table 3 A : Age, sex and area of residence sample distribution, 2011

	2011 ABS Census South Australia	2011 SAMSS	Difference in proportions
Age groups			
0 to 9 years	11.9	8.1	-3.8
10 to 15 years	7.4	5.9	-1.5
16 to 34 years	24.4	14.6	-9.9
35 to 44 years	13.5	6.2	-7.4
45 to 54 years	14.1	11.7	-2.4
55 to 64 years	12.5	19.9	7.4
65 to 74 years	8.3	18.2	9.9
75 years and over	7.8	15.5	7.7
Sex			
Male	49.3	44.1	-5.2
Female	50.7	55.9	--5.2
Area of residence			
Metropolitan Adelaide	71.6	70.5	-1.1
SA Country	28.4	29.5	1.1

Individual characteristics

Country of birth was obtained for all SAMSS survey respondents. Table 3 B shows, the sample from SAMSS had a higher proportion of people born in Australia and United Kingdom, and a lower proportion of Aboriginal and/or Torres Strait Islanders (ATSI) and people born overseas (not including UK and Europe). It would have been ideal to include ATSI category as one of the margin categories, but the number and proportion of ATSI respondents (each month) was less than the recommendation of at least 5% (1.0%).

Table 3 B Country of birth sample distribution, all ages

	2011 ABS Census South Australia	2011 SAMSS	Difference in proportions
Australia – non ATSI	75.0	78.4	3.4
Australia – ATSI	1.9	1.0	-0.9
United Kingdom	8.3	11.1	2.8
Europe	5.4	5.4	0.0
Other	9.5	4.1	-5.4

Note: ATSI denotes Aboriginal or Torres Strait Islander; ABS Tablebuilder variable: BPLP - 4 Digit Level by STATE and INGP.

SAMSS data collects social marital status, and ABS 2011 Census collects both the registered and social (current living arrangements) marital status. Table 3 C shows the decision of how the SAMSS marital status categories fit with the two Census variables.

Table 3 C Variable and category agreement between ABS 2011 Census and SAMSS: Marital Status

MSTP (person's individual's current living status in regard to a registered marriage)	MDCP (persons relationship status based on their current living arrangements)			
	Married in a registered marriage	Married in a de facto marriage	Not married	Not applicable
Never married	Married/de facto	Married/de facto	Never married	Never married
Widowed	Married/de facto	Married/de facto	Widowed	Widowed
Divorced	Married/de facto	Married/de facto	Separated / divorced	Separated / divorced
Separated	Married/de facto	Married/de facto	Separated / divorced	Separated / divorced
Married	Married/de facto	Married/de facto	Married/de facto	Married/de facto

Note: SAMSS question is "What is your current marital status? " with options read out: 1) Married; 2) Living with a partner (de facto); 3) Divorced; 4) Separated; 5) Widowed; 6) Never married. ABS Tablebuilder variable: MDCP and MSTP.

Given there were assumptions on which categories from the cross-tabulation of the registered and social marital status categories from the Census that seemed inconsistent (ie registered the person as married, but the same person was classified as not married or not applicable within social marital status), it was decided that the social marital status variable would be used for raking. Table 3 D shows that SAMSS had more people who were widowed and less never married.

Table 3 D : Marital status sample distribution, all ages

	2011 ABS Census South Australia	2011 SAMSS	Difference in proportions
	MSTP & MDCP	**"What is your current marital status? "**	
Married/Living with partner	46.9	46.4	-0.4
Separated/Divorced	7.9	9.9	2.0
Widowed	5.0	12.1	7.0
Never Married	20.9	17.7	-3.3
Under 16	19.2	13.9	-5.3
	MDCP		
Married/Living with partner	43.2	46.4	3.3
Other	37.6	39.6	2.0
Under 16	19.2	13.9	-5.3

Note: ABS Tablebuilder variable: MSTP, MDCP

SAMSS asks one question to ascertain the respondent's highest level of educational attainment. It is difficult to match the categories between SAMSS and Census; in particular for those with those with diploma or certificate level education. Therefore, it was decided to categorise those who has at least a tertiary level of education (Table 3 E). SAMSS had a higher proportion of people who had at least a tertiary level of education (Table 3 G).

Table 3 E Variable and category agreement between ABS 2011 Census and SAMSS: Educational attainment

	2011 ABS Census South Australia	2011 SAMSS
	QALLP	**"What is the highest level of education you have completed?"**
Degree or higher	Postgraduate Degree Level Graduate Diploma and Graduate Certificate Level Bachelor Degree Level	University, CAE or some other tertiary institute degree
None, primary, secondary, trade, certificate, diploma	Level of education not stated Advanced Diploma and Diploma Level Certificate Level Not applicable	Never attended school Some primary school Completed primary school Some high school Completed high school TAFE, trade certificate or diploma

Note: ABS Tablebuilder variable: QALLP - 1 Digit Level

Current employment status including the number of hours work in a usual week was obtained for all SAMSS survey respondents. Table 3 F shows how SAMSS employment status fit with the census variable. SAMSS had a higher proportion of people who were classified as economically inactive i.e. home duties, student, retired or unable to work (Table 3 G).

Table 3 F Variable and category agreement between ABS 2011 Census and SAMSS: Employment Status

	2011 ABS Census South Australia	2011 SAMSS
	LFS06P	"Which of these best describes your current employment status? Are you" "How many hours do you work per week?"
Full time employed	Employed, worked full-time Employed, away from work	Self employed, 35+ hours per week Employed for wages, salary or payment in kind, 35+ hours per week
Part time employed	Employed, worked part-time	Self employed, <35 hours per week Employed for wages, salary or payment in kind, <30 hours per week
Unemployed	Unemployed, looking for full-time work Unemployed, looking for part-time work	Unemployed
Economically inactive (Home duties, student, retired, unable to work)	Not in the labour force	Engaged in home duties Student Retired Unable to work Other

Table 3 G Educational attainment and Employment status sample distribution, all ages

	2011 ABS Census South Australia	2011 SAMSS	Difference in proportions
Educational attainment			
None to some high school, trade, certificate, diploma	69.8	70.5	0.7
Degree or higher	11.0	15.6	4.6
Under 16	19.2	13.9	-5.3
Employment status			
Full time employed	31.2	23.8	-7.4
Part time employed	17.1	14.4	-2.7
Unemployed	2.9	1.5	-1.4
Economically inactive (Home duties, student, retired, unable	29.6	46.3	16.7
Under16	19.2	13.9	-5.3

Note: ABS Tablebuilder variable: QALLP - 1 Digit Level, LFS06P

Household characteristics

SAMSS had a lower proportion of low SES households and an indicator for low SES is people who rent. Table 3 H shows the classifications made for dwelling status for both 2011 Census and SAMSS.

Table 3 H Variable and category agreement between ABS 2011 Census and SAMSS: Dwelling Status

	2011 ABS Census South Australia	2011 SAMSS
	TEND	"Is this dwelling?"
Owned or being purchased	Owned outright Owned with a mortgage Being purchased under a rent/buy scheme	Owned or being purchased
Renting	Rented	Rented from the Housing Trust Rented privately
Other	Being occupied rent-free Being occupied under a life tenure scheme Other tenure type	Community Housing Retirement Village Other

SAMSS had a lower proportion of respondents who were renting compared to non-renters (low SES households) (Table 3 I). As of July 2012, SAMSS surveys will separate the category of those households that are "owned outright" or "owned with a mortgage".

Table 3 I Household characteristics sample distribution, all ages

	2011 ABS Census South Australia	2011 SAMSS	Difference in proportions
Number of people in household			
1	26.4	25.5	-0.9
2	34.7	39.9	5.2
3	15.5	12.4	-3.1
4+ people	23.4	22.2	-1.2
Dwelling tenure status			
Owned or being purchased	69.7	84.4	14.7
Renting	27.8	11.5	-16.3
Other	2.6	4.1	1.5

Note: ABS Tablebuilder variable: NPRD, TEND, HCFMD

APPENDIX 4: CONFERENCE PRESENTATION

Poster: Can telephone surveys be used for collecting health information in Australia?

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Background In the last 15 years, telephone surveys have become a standard method of collecting health information in Australia. The last decade have seen rapid changes to telecommunications technologies, whereby households replacing landline telephones with mobiles and Voice over Internet Protocol (VoIP). This change has significant impact on the representativeness of telephone samples, and whether telephone surveys can continue to be used to reliably collect representative information regarding health status and health risk behaviours.

Aims This presentation will explore the potential bias due to non-coverage in the telephone samples used for household telephone surveys in Australia by various sociodemographics and health indicators (for example diabetes, asthma, smoking status, obesity) using data collect in 2011.

Methods Since 1999 in South Australia questions on telephone ownership/use and listings of telephone number in accessible directory have been asked in a non-telephone based survey, Health Omnibus Survey (HOS). HOS is a face-to-face household survey, conducted annually in metropolitan and country South Australia. Methodology is consistent and each year over 3000 adults (aged 15 years and above) are personally interviewed in their home.

Results Preliminary results has shown that the proportion of households with a mobile only household has risen from 1% in 1999 to 14% in 2010, to 22% in 2011. The proportion of households with a landline connected has dropped since 2006 (94%) to 85% in 2011.

Conclusions Coverage of households with a telephone connected (landline) and the adequacy of the sampling frame(s) have been a concern for those involved in epidemiologically-sound telephone surveys. Researchers need to be aware of these telephone sampling issues when considering telephone surveys.

APPENDIX 5: REPRINTS OF PUBLISHED PAPERS

1. Dal Grande E, Chittleborough CR, Campostrini S, Taylor AW. Bias of health estimates obtained from chronic disease and risk factor surveillance systems using telephone populaiton surveys in Australia. Results from a representative face-to-face survey in Australia from 2010 to 2013. BMC Med Res Methodol. 2016.

2. Dal Grande E, Chittleborough CR, Campostrini S, Tucker G, Taylor AW. Health Estimates Using Survey Raked-Weighting Techniques in an Australian Population Health Surveillance System. Am J Epidemiol. 2015;182(6):544-556.

3. Dal Grande E, Chittleborough CR, Campostrini S, Dollard M, Taylor AW. Pre-Survey Text Messages (SMS) Improve Participation Rate in an Australian Mobile Telephone Survey: An Experimental Study. PLoS ONE. 2016;11(2):e0150231.

RESEARCH ARTICLE

CrossMark

Bias of health estimates obtained from chronic disease and risk factor surveillance systems using telephone population surveys in Australia: results from a representative face-to-face survey in Australia from 2010 to 2013

Eleonora Dal Grande[1*], Catherine R. Chittleborough[2], Stefano Campostrini[3] and Anne W. Taylor[1]

Abstract

Background: Emerging communication technologies have had an impact on population-based telephone surveys worldwide. Our objective was to examine the potential biases of health estimates in South Australia, a state of Australia, obtained via current landline telephone survey methodologies and to report on the impact of mobile-only household on household surveys.

Methods: Data from an annual multi-stage, systematic, clustered area, face-to-face population survey, Health Omnibus Survey (approximately 3000 interviews annually), included questions about telephone ownership to assess the population that were non-contactable by current telephone sampling methods (2006 to 2013). Univariable analyses (2010 to 2013) and trend analyses were conducted for sociodemographic and health indicator variables in relation to telephone status. Relative coverage biases (RCB) of two hypothetical telephone samples was undertaken by examining the prevalence estimates of health status and health risk behaviours (2010 to 2013): directory-listed numbers, consisting mainly of landline telephone numbers and a small proportion of mobile telephone numbers; and a random digit dialling (RDD) sample of landline telephone numbers which excludes mobile-only households.

Results: Telephone (landline and mobile) coverage in South Australia is very high (97 %). Mobile telephone ownership increased slightly (7.4 %), rising from 89.7 % in 2006 to 96.3 % in 2013; mobile-only households increased by 431 % over the eight year period from 5.2 % in 2006 to 27.6 % in 2013. Only half of the households have either a mobile or landline number listed in the telephone directory. There were small differences in the prevalence estimates for current asthma, arthritis, diabetes and obesity between the hypothetical telephone samples and the overall sample. However, prevalence estimate for diabetes was slightly underestimated (RCB value of −0.077) in 2013. Mixed RCB results were found for having a mental health condition for both telephone samples. Current smoking prevalence was lower for both hypothetical telephone samples in absolute differences and RCB values: −0.136 to −0.191 for RDD landline samples and −0.129 to −0.313 for directory-listed samples.

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Conclusion: These findings suggest landline-based sampling frames used in Australia, when appropriately weighted, produce reliable representative estimates for some health indicators but not for all. Researchers need to be aware of their limitations and potential biased estimates.

Keywords: Bias, Telephone sampling methodology, Sampling frame, Public health surveillance, Health surveys, Chronic conditions, Risk factors

Background

Many established population-based, continuous chronic disease and behavioural risk factor surveillance systems worldwide utilise Computer Assisted Telephone Interviewing (CATI) [1–9]. Since the 1990s, CATI surveys have been seen as an ideal tool since they are effective, relatively inexpensive, flexible and timely [6, 8–12]. However, over the past 15 years vast changes have occurred in the telecommunication industry (mobile telephone and internet) and society's acceptance of, and engagement with, these new technologies [13, 14]. The new communication technologies have had an impact on population-based telephone surveys, specifically, the diminishing coverage of traditional sampling frames and declining response rates [11, 15] resulting in increased costs [16, 17] and potential bias in survey estimates [18, 19].

In the early 1990s, 95–97 % of Australian households had a landline telephone connected [20] and response rates of around 70–80 % were the norm [20–24]. For population health surveys in Australia, two sampling methodologies were used: directory-listed telephone numbers, referred to as Electronic White Pages (EWP) and random digit dialling (RDD) of landline telephone numbers [3, 20, 22]; both methods having the ability to target geographical areas (state, suburbs or postcodes) which has contributed to the utility and efficiency of telephone surveys [25, 26]. EWP consists mainly of listed landline telephone numbers with name and address details for a household or business which the sampling frame can be easily stratified by state, suburb or postcode. EWP has mobile and Voice over Internet Protocol (VOIP) telephone numbers but only as a small proportion of the total sample. One drawback of EWP is that it does not include unlisted (silent) telephone number; that is, households which have opted, at a cost, to exclude their landline telephone number from the EWP. RDD methods have been developed to include silent landline telephone numbers based on the prefixes of the landline telephone numbers. Some of these methods use the EWP, known as list-assisted RDD (LA-RDD), to make the sampling frame more efficient by removing blocks of numbers that have a high chance of not being connected or are assigned to large businesses [3, 27]. These RDD methods do not include mobile or VoIP telephone numbers. Since the turn of this century, there has been a trend of households moving away from traditional landline telephones with the emergence of mobile-only households [11, 13, 15, 28]. This is due to increasing portability, flexibility, affordability and broadening internet capability of mobile telephones including smartphones and other telecommunications, such as VoIP [11, 15, 26, 29–32].

As a result of the increasing use of mobile telephones, conducting telephone surveys has become increasingly problematic in Australia and other countries [15, 33]. This is because of the difficulty in obtaining a representative sampling frame of mobile telephones numbers since are they are rarely listed (7.3 % of mobile telephone owners in South Australia are listed [26]). Unlike the structure of landline telephone numbers, the Australian mobile numbers do not provide details of geographical location and the common methods used to generate a RDD sample of landline telephone numbers geographically are not applicable to mobile telephone numbers [34, 35]. In 2011–12, approximately 20 % of households in Australia were mobile-only [14, 29], 34 % of USA households in 2012 were mobile-only [30] with countries in Europe reporting 50–70 % [32]. More notably, studies have found that mobile-only households are demographically different to traditional landline households: they are generally younger people, unrelated, never married, and socioeconomically disadvantaged [26, 30]. These issues suggest that by excluding mobile-only households biased estimates may be produced from chronic disease and behavioural risk factor surveillance systems.

This study presents the most up-to-date estimates available on the current status and possible sample biases of the current telephone survey methodology in South Australia, a state of Australia. Data from an annual representative face-to-face (non-telephone) population survey that included questions about telephone ownership were used to assess the population that were non-contactable by current telephone sampling methods. This included both household landline and mobile telephone ownership and listings in the telephone directory. This study will 1) explore trends of landline and mobile telephone ownership between 2006 and 2013; 2) describe the socio-demographic characteristics of respondents living in mobile-only households between 2010 and 2013; and 3) investigate the coverage bias of the two telephone samples

(directory-listed numbers (EWP), consisting mainly of landline telephone numbers and a small proportion of mobile and VoIP telephone numbers; and a RDD sample of landline telephone numbers which excludes mobile-only households) by examining the prevalence estimates of health status and health risk behaviours between 2010 and 2013. This is one of the few studies to assess the potential bias of health estimates due to coverage bias from telephone sampling frames in terms of health indicators and socio-demographics, using a unique data source with telecommunication information on people who would be excluded from the hypothetical telephone samples [26, 30]. This study uses relatively current data, which is important since telecommunications technologies have rapidly changed and evolved over the last 10 years, with increased uptake and saturation of mobile telephones and associated changes in the way people communicate [36]. Methodological studies therefore need to continually assess sample coverage and potential bias in health-related estimates [26].

Methods

Survey design and sample selection

The Health Omnibus Survey (HOS) [37, 38] is a multi-stage, systematic, clustered area sample of South Australian households where face-to-face interviews are conducted annually. The HOS sample includes households randomly selected from Australian Bureau of Statistics (ABS) collector districts (CDs) (2006 to 2012) and Statistical Areas Level 1 (SA1) (2013), from the metropolitan Adelaide area and country towns with a population of 1,000 people or more. Within each CD or SA1, a random starting point was selected and from this point 10 households were selected in a given direction with a fixed skip interval. Hotels, motels, hospitals, hostels and other institutions were excluded from the sample. An approach letter and a brochure introducing the survey were sent to the selected household and the person aged 15 years or over, with the last birthday, was chosen for interview. The interviews were conducted in people's homes by trained interviewers. Up to six call back visits were made to chosen households to interview the selected person. There was no replacement for non-respondents and no incentive of any kind was offered. Approximately 3000 people participate annually, achieving a median response rate of 59.3 % (range: 52 to 60 %). The data are weighted by five year age groups, sex, and area (metropolitan Adelaide and rural/remote South Australia) to the most recent Census or Estimated Residential Population for South Australia and probability of selection within the household size to provide population estimates.

Household telecommunications ownership

Questions regarding telecommunications services in the household, specifically, landline telephone and mobile connections, were included in the 2006 to 2013 HOS. Mobile-only households were defined if the respondent had a mobile telephone with no working landline connection to the household. Landline connections did not include using VoIP connection or Skype for telephone calls. In addition, questions were asked regarding landlines and mobile telephones currently listed in the Australian White Pages. From these questions, household landline and mobile telecommunication status were determined by classifying the respondents as living in mobile-only households; landline-only households; landline and mobile telephone households; or having no landline or mobile in the household.

Socio-demographics

Demographic variables included age, sex, area of residence, country of birth, household size, household structure, educational attainment, marital status, gross annual household income, employment status, dwelling ownership or renting status (2013 only) and area-level socio-economic status. The Socio-Economic Indexes for Areas (SEIFA) Index of Relative Socio-Economic Disadvantage (IRSD) is a composite score of relative disadvantage developed by the ABS [39] for particular geographical areas, such as postcodes. It is based on selected 2011 Census socio-demographic variables. The SEIFA IRSD scores were grouped into quintiles for analysis where the highest quintile comprised postcodes with the highest SEIFA IRSD scores (most advantaged areas).

Comorbid conditions and health behaviours

Chronic conditions included self-reported medically confirmed diabetes (2010, 2011 and 2013 only), current asthma (2010 and 2011 only), arthritis and a current mental health condition. Self-reported health risk factor data included smoking status and obesity as determined by body mass index (BMI) which was derived from self-reported weight and height and recoded into four categories (underweight, normal weight, overweight and obese) [40].

Statistical analyses

Data analysis was conducted using Stata Version 12.0. All estimates and analyses were conducted using *svy* commands in Stata to incorporate the sampling design. Univariable analyses using chi-square tests compared the proportion of mobile-only households across socio-demographic variables for 2010, 2011, 2012 and 2013. Households that had no telecommunications, refused or where the status could not be determined were excluded from the analyses ($n = 39$). The univariable analyses were limited to data from 2010, since data has been previously published for earlier years [26]. Additional univariable analyses using chi-square tests were undertaken to

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describe the proportion of households with a landline telephone connected; the proportion of households with mobile telephones; and the proportion of households with a directory-listed telephone number (EWP). These results can be found in Additional file 1.

To explore the possibility of coverage bias of telephone surveys, two hypothetical telephone sampling frames (subsamples) were created from HOS: 1) RDD landline, that is, households that had a landline connection (mobile-only households excluded); and 2) directory-listed numbers, that is, households with either a landline or mobile telephone number listed in the White Pages. Prevalence estimates of health conditions and behavioural risk factors were presented for the overall population, and the two hypothetical telephone samples. The hypothetical telephone samples were subsamples of the total sample (landline RDD sample is 72–78 % of the total sample and directory-listed landline sample is 50–60 % of the total sample) which means that these subsamples would have a different demographic profile to each other and the overall sample. Therefore the data for the hypothetical telephone samples were re-weighted to produce health estimates that are reflective of the South Australian population. Re-weighting is calculated by incorporating the original relative sample weights, and by age, sex and area of residence to the most recent Census or Estimated Residential Population for South Australia.

To determine the amount of bias of the prevalence estimates derived from the two hypothetical sampling frames, the relative coverage bias (RCB) was calculated by the following formula: $\frac{N_{nc}}{N} \cdot \frac{(p_c - p_{nc})}{P}$ [41]. This formula incorporates the proportion of the population that is not included in the hypothetical samples (N_{nc}/N), that is, 1) mobile-only households, and 2) households that do not have either a mobile or landline telephone number listed in the telephone directory (N_{nc} denotes the number in the sample that is not covered in the total sample, N). It also includes the differences in prevalence estimate obtained from the hypothetical samples, p_c, and from the sample not in the hypothetical samples, p_{nc}, divided by the prevalence estimate for the total population, P.

Results

Figure 1 shows the household landline and mobile telephone status from 2006 to 2013. Mobile telephone ownership was consistently around 90 % during the last eight years, rising from 89.7 % (95 % CI 88.5–90.9) in 2006 to 96.3 % (95 % CI 95.5–97.0) in 2013 (7.4 % increase). The proportion of households that are mobile-only has increased by 431 % over the eight year period from 5.2 % (95 % CI 4.4–6.0) in 2006 to 27.6 % (95 % CI 24.7–30.7) in 2013. In contrast, the proportion of landline ownership (households with landline telephone only, and households with both landline and mobile telephones) has decreased by 24.1 % from 94.4 % (95 % CI 93.2–95.) in 2006, 87.3 % (95 % CI 85.7–88.8) in 2009 to 71.7 % (95 % CI 68.6–74.6) in 2013. Descriptive statistics for the participants for 2010 to 2013 are provided in Additional file 1: Table S1.

Table 1 shows the proportion of respondents living in mobile-only households by socio-demographic variables across the four years. Generally, respondents living in mobile-only household were more likely to be male, younger, of Aboriginal or Torres Strait Islander descent, born in Asia or countries other than Australia, UK,
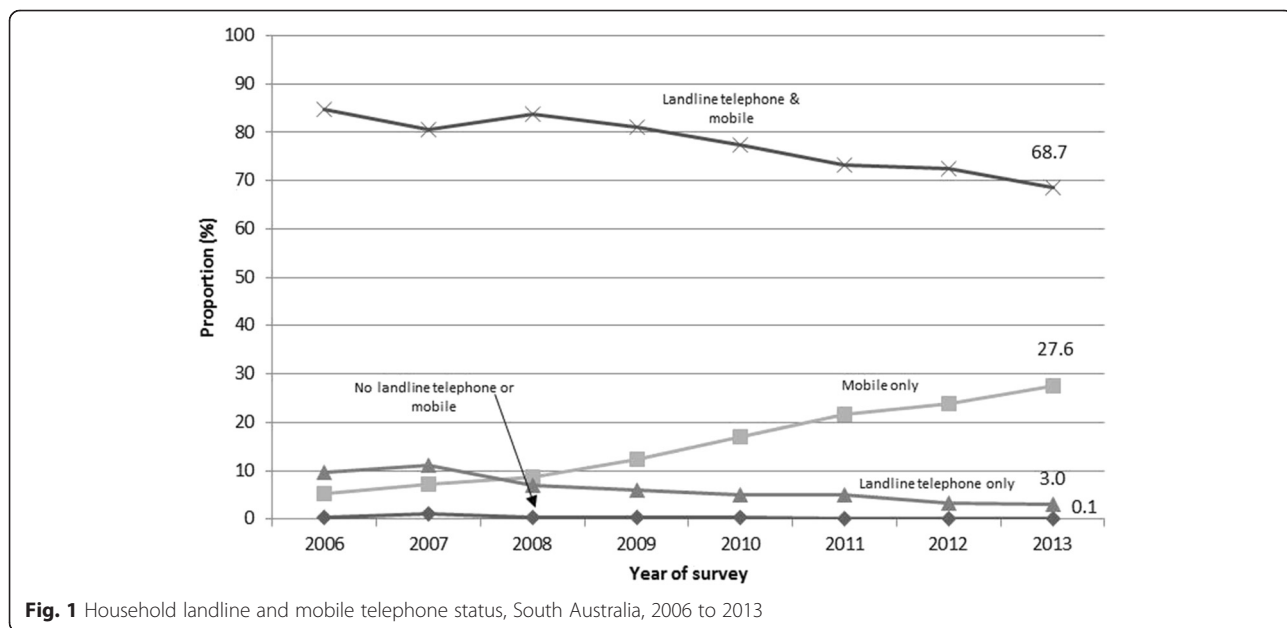
Fig. 1 Household landline and mobile telephone status, South Australia, 2006 to 2013

Table 1 Proportion of respondents living in mobile only households by socio-demographic variables, 15 years and over

	2010			2011			2012			2013		
	n	% (95 % CI)	p value	n	% (95 % CI)	p value	n	% (95 % CI)	p value	n	% (95 % CI)	p value
Sex												
Male	300	20.1 (17.5–22.9)	<0.001	339	22.8 (20.4–25.4)	0.158	391	26.2 (23.4–29.2)	0.005	409	28.8 (24.6–33.3)	0.288
Female	221	14.2 (12.3–16.3)		318	20.6 (18.1–23.3)		338	21.6 (19.5–23.9)		394	26.5 (23.6–29.6)	
Age (years)												
15 to 24	120	23.7 (18.9–29.3)	<0.001	145	28.7 (23.2–34.8)	<0.001	168	34.4 (28.4–41.0)	<0.001	171	36.9 (30.5–43.8)	<0.001
25 to 34	189	39.8 (34.7–45.1)		226	47.9 (42.4–53.4)		225	47.6 (41.8–53.6)		254	56.6 (49.2–63.7)	
35 to 44	96	18.8 (15.0–23.2)		149	29.1 (24.8–33.9)		146	28.9 (24.9–33.3)		168	35.0 (29.4–41.1)	
45 to 54	66	12.5 (9.7–15.9)		69	13.3 (10.2–17.0)		95	18.0 (14.5–22.2)		110	22.1 (17.5–27.6)	
55 to 64	31	7.0 (4.8–9.9)		36	8.0 (5.3–12.0)		69	14.9 (11.6–19.0)		61	13.7 (11.1–16.7)	
65 to 74	10	3.2 (1.9–5.3)		25	7.6 (5.4–10.6)		20	5.5 (3.8–7.7)		29	8.3 (6.1–11.2)	
75+	7	2.9 (1.5–5.5)		6	2.6 (1.3–5.1)		7	2.8 (1.4–5.4)		10	4.3 (2.5–7.2)	
Area of residence												
Metropolitan	369	16.4 (14.7–18.3)	0.315	461	20.6 (18.7–22.7)	0.122	503	22.2 (20.3–24.3)	0.005	549	25.4 (22.4–28.6)	0.016
Regional	151	18.9 (14.7–23.9)		196	24.6 (20.0–29.9)		226	28.5 (24.6–32.7)		254	34.1 (27.7–41.0)	
Number of people in household												
1	95	23.6 (20.6–26.8)	0.001	125	29.7 (26.4–33.3)	0.001	117	28.6 (23.4–34.4)	0.064	135	36.0 (31.2–41.0)	<0.001
2	267	16.7 (14.5–19.2)		352	22.5 (20.4–24.8)		397	24.9 (22.6–27.3)		433	28.6 (25.3–32.2)	
3	110	19.0 (15.2–23.3)		84	16.7 (12.7–21.7)		110	20.3 (16.3–25.1)		140	27.2 (21.6–33.6)	
4 or more	47	10.2 (6.6–15.6)		96	17.5 (12.8–23.4)		106	20.7 (15.9–26.5)		95	18.8 (14.9–23.4)	
Country of birth												
Australia	396	17.4 (15.5–19.5)	<0.001	488	22.0 (19.7–24.4)	<0.001	537	23.7 (21.6–26.0)	<0.001	595	27.9 (24.8–31.1)	0.002
UK or Ireland	25	9.3 (6.2–13.7)		39	13.7 (10.2–18.3)		61	17.9 (14.3–22.3)		60	20.3 (14.3–28.0)	
Europe	13	8.9 (5.3–14.6)		17	10.6 (6.6–16.7)		9	7.4 (3.9–13.8)		21	14.5 (10.8–19.1)	
Asia	47	29.8 (21.3–39.9)		78	32.9 (25.8–40.7)		81	41.0 (31.7–50.9)		74	35.8 (24.2–49.4)	
Other	39	19.9 (13.4–28.5)		34	26.4 (18.2–36.7)		41	31.7 (22.7–42.3)		53	42.4 (30.2–55.6)	
Aboriginal/Torres Strait Islander												
No	502	16.8 (15.0–18.7)	0.029	627	21.1 (19.2–23.1)	<0.001	686	23.1 (21.3–25.0)	<0.001	764	27.1 (24.3–30.0)	<0.001
Yes	18	35.2 (21.9–51.2)		29	53.2 (38.6–67.3)		39	51.5 (36.1–66.5)		36	53.9 (38.4–68.8)	
Household structure												
Couple family children	135	12.6 (10.3–15.5)	<0.001	209	18.1 (15.4–21.2)	<0.001	232	21.2 (18.1–24.6)	<0.001	227	21.6 (18.0–25.6)	<0.001
One parent family, other	79	22.9 (18.2–28.3)		92	31.2 (25.4–37.7)		88	29.7 (24.7–35.1)		136	40.7 (35.0–46.7)	

Table 1 Proportion of respondents living in mobile only households by socio-demographic variables, 15 years and over *(Continued)*

Lone adult person	77	21.5 (18.3–25.1)		99	26.8 (23.3–30.7)		95	26.5 (21.7–31.9)		99	31.2 (26.6–36.3)
Couple with no children	89	11.3 (9.0–14.1)		126	15.7 (13.2–18.6)		145	16.9 (14.3–19.9)		138	19.5 (16.7–22.6)
Other	139	28.8 (23.7–34.5)		131	31.6 (26.1–37.6)		169	37.7 (31.5–44.4)		203	40.7 (34.5–47.2)
Marital status											
Married/defacto	253	13.3 (11.5–15.3)	<0.001	335	17.9 (15.8–20.2)	<0.001	390	20.5 (18.2–22.9)	<0.001	417	23.3 (20.1–26.8)	<0.001
Separated/Divorced	46	21.4 (17.2–26.3)		75	30.5 (25.5–36.0)		88	33.6 (28.4–39.2)		91	34.4 (30.0–39.1)
Widowed	9	5.1 (2.9–8.7)		12	7.6 (4.8–12.0)		14	8.1 (5.3–12.1)		16	11.7 (8.3–16.4)
Never married	207	28.1 (24.1–32.5)		233	31.0 (26.8–35.7)		237	33.4 (28.9–38.3)		279	38.9 (33.9–44.1)
Educational attainment											
Secondary schooling	212	15.3 (13.0–17.9)	0.128	268	21.5 (18.4–25.0)	0.819	292	23.3 (20.3–26.7)	0.702	329	27.7 (23.3–32.6)	0.745
Trade, certificate, diploma	192	18.7 (16.2–21.5)		246	21.2 (18.7–23.8)		272	24.3 (21.6–27.3)		293	27.6 (24.2–31.2)
Bachelor degree or higher	115	18.3 (15.3–21.8)		141	22.9 (19.4–26.8)		165	24.2 (20.7–28.1)		181	27.7 (23.4–32.5)
Gross annual household income											
Up to $20,000	45	16.0 (11.4–22.0)	0.073	47	17.3 (13.3–22.2)	0.042	58	24.4 (19.7–29.7)	0.25	53	30.3 (23.9–37.4)	0.005
$20,001 – $40,000	71	17.3 (13.7–21.5)		80	20.0 (16.0–24.7)		87	25.2 (20.7–30.4)		80	21.6 (16.6–27.6)
$40,001 – $80,000	114	18.8 (15.4–22.7)		157	26.5 (22.8–30.7)		161	27.6 (23.8–31.8)		189	33.6 (28.9–38.5)
$80,001 – $120,000	106	21.0 (17.2–25.5)		117	24.3 (20.1–29.1)		99	24.0 (19.6–29.0)		126	28.8 (23.9–34.3)
$120,001 or more	57	13.1 (9.8–17.1)		86	19.1 (15.1–23.8)		115	21.7 (17.8–26.1)		151	25.9 (21.6–30.7)
Not stated	128	15.8 (12.9–19.1)		169	20.3 (16.2–25.2)		210	22.1 (18.7–25.8)		203	26.1 (22.2–30.5)
Employment status											
Fulltime employed	248	21.9 (19.1–25.1)	<0.001	315	26.9 (24.0–30.1)	<0.001	309	27.7 (24.7–31.0)	<0.001	371	36.2 (30.9–41.9)	<0.001
Parttime employed	108	18.4 (14.6–22.9)		128	22.0 (18.2–26.2)		135	24.5 (20.5–28.9)		157	26.5 (22.2–31.3)
Home Duties	46	22.8 (17.5–29.3)		55	32.7 (25.4–40.9)		58	27.6 (21.8–34.3)		55	34.4 (27.1–42.6)
Unemployed	23	35.8 (23.7–50.2)		32	35.2 (24.1–48.1)		51	57.7 (45.4–69.2)		40	42.0 (28.4–56.8)
Retired	20	3.2 (2.1–4.9)		35	5.7 (4.1–7.9)		36	5.9 (4.4–7.7)		44	7.5 (5.5–10.2)
Student	43	14.7 (10.2–20.7)		51	21.1 (14.3–29.9)		98	29.7 (23.0–37.3)		81	29.2 (23.3–36.0)
Other/not working due to health	32	20.0 (13.0–29.5)		38	23.4 (18.1–29.7)		41	28.8 (21.6–37.2)		53	32.6 (25.1–41.2)
SEIFA IRSD quintile											
Lowest (most disadvantaged)	160	22.3 (18.1–27.1)	0.003	197	27.3 (23.4–31.5)	<0.001	227	30.3 (26.6–34.3)	<0.001	229	34.6 (28.1–41.7)	0.004
Low	86	17.8 (14.9–21.1)		179	29.3 (24.5–34.6)		137	26.8 (22.2–32.0)		186	31.0 (25.8–36.8)
Middle	106	17.0 (13.5–21.3)		110	20.6 (16.8–25.0)		139	25.2 (21.2–29.6)		142	28.0 (21.8–35.1)
High	84	15.1 (11.8–19.1)		81	15.7 (12.7–19.3)		110	19.8 (16.2–24.0)		120	22.2 (16.8–28.7)

Highest (least disadvantaged)	84	12.6 (9.8–16.1)	91	13.9 (11.2–17.1)	116	16.9 (13.8–20.4)	125	21.0 (17.5–25.0)	
Dwelling status									
Owned or being purchased							396	18.3 (16.1–20.7)	<0.001
Rent from state government (public housing)							61	43.5 (34.5–52.9)	
Rent privately							330	58.6 (52.8–64.3)	
Other							9	33.4 (15.7–57.6)	
Overall	520	17.1 (15.3–19.0)	657	21.7 (19.7–23.8)	729	23.9 (22.0–25.9)	803	27.6 (24.7–30.7)	

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Ireland or Europe, never married, or separated or divorced, unemployed, fulltime employed, or home duties, renting privately or from the government, and to reside in the most disadvantaged areas. Largest percentage increases over the four years occurred amongst females (86.6 %), people in the older age groups (86.2–159.4 %), people living in rural areas of South Australia (80.4 %), people born in the United Kingdom or Ireland (118.3 %), people living in single parent households or shared-care parenting households (77.7 %), or couples with no children (72.6 %), widowed (131.4 %), married or in a defacto relationship (75.2 %), people with at least secondary schooling (81.0 %), people living in households on low income levels (89.4 %) or very high income levels (97.7 %), and people who are retired (134.4 %) or who are currently students (98.6 %).

Additional file 1: Tables S2 and S3 show the proportion of respondents living in a household with a landline connection and the proportion of respondents living a household with at least one mobile telephone by socio-demographic variables for 2010 to 2013. The proportion of respondents living in households with directory-listed mobile or landline telephone (EWP) has been steadily decreasing from 73.8 % (95 % CI 72.2–75.4) in 2006, to 60.4 % (95 % CI 58.1–62.7) in 2010 and 49.6 % (95 % CI 46.2–53.0) in 2013. This proportion by socio-demographic characteristics for 2010 to 2013 is listed in Additional file 1: Table S4. In 2013, 4.6 % (95 % CI 3.8–5.5) of mobile numbers were listed in the telephone directory compared to 62.7 % (95 % CI 59.2–66.1) of landlines.

The prevalence estimates of various health conditions and behavioural risk factors for all households, for people who live in households with a landline connection (hypothetical landline RDD sample) and for people who live in a household with a directory-listed landline or mobile telephone number (hypothetical directory-listed sample) are shown in Table 2. The RCB for the prevalence estimates derived from the two hypothetical samples are also in Table 2. There were small absolute differences in the prevalence estimates for current asthma, arthritis and obesity between the hypothetical telephone samples and the overall sample. The prevalence estimates for diabetes by the two hypothetical samples did not differ in 2010 and 2011, however, the prevalence estimate was slightly underestimated (RCB value of −0.077) in 2013 for the directory-listed sample. Even though the prevalence estimates for arthritis were similar for both hypothetical samples, the prevalence estimate for arthritis in 2010 was underestimated for the directory-listed sample (RCB value of −0.083) compared to the overall sample (prevalence of 20.7 vs. 21.4 %). The prevalence of having a mental health condition showed mixed results for both

hypothetical samples and over time: the prevalence of having a mental health condition was underestimated for both samples with estimates from the directory-listed sample having larger RCB (ranging from −0.102 to −0.242) with the exception of 2011, which had the opposite result of overestimating mental health conditions (RCB value of 0.056). Current smoking prevalence was lower for both hypothetical telephone samples with absolute differences ranging from 2.9 to 3.4 percentage points for RDD landline samples and 3.3 to 5.3 percentage points for directory-listed samples, and associated large RCB values: −0.136 to −0.191 for RDD landline samples and −0.129 to −0.313 for directory-listed samples.

Discussion

This paper presents estimates and trends of telephone coverage in Australia from 2006 to 2013. Continual assessment of methodological issues around conducting population health telephone surveys is essential due to the rapid technological changes in telecommunications and the different 'user culture' associated in use of these new and old telecommunication technologies. Even though telephone (landline and mobile) coverage in South Australia is very high (97 %), nearly a third of households are mobile-only (27.8 %) and only half of the households (49.0 %) have either a mobile or landline number listed in the White Pages telephone directory. Our results show that mobile-only respondents are different across a range of socio-demographic indicators, which is similar to international studies [13, 15, 30]. Using hypothetical sampling frames (RDD landline and EWP directory listing) that were weighted to the age and sex structure of the South Australian population produced contradictory results for health prevalence estimates when compared to all households in the face-to-face survey. Prevalence estimates of diabetes, current asthma, arthritis and obesity had very minor differences and biases, but the prevalence estimates for mental health condition and current smoking indicates biases using either RDD landline or EWP directory listing sampling frame. Even though our results show that mobile-only respondents are demographically different across a range of socio-demographic indicators, appropriately weighted data can produce reliable prevalence estimates for some health indicators, but not for others. These findings suggest landline-based sampling frames used in Australia are potentially biased for some health indicators, such as current smokers and having a mental health condition, particularly where conditions or risk factors are higher amongst those living in mobile-only households. Researchers using either RDD or directory-listing landline sampling frames need to be aware of their limitations and know of the potential biased

Table 2 Prevalence of health conditions and risk factors for all households, and for landline Random Digit Dialling (RDD) and Directory-listed (EWP) telephone samples, 15 years and over

		2010			2011			2012			2013		
		n	% (95 % CI)	RCB	n	% (95 % CI)	RCB	n	% (95 % CI)	RCB	n	% (95 % CI)	RCB
	Health conditions												
Diabetes	All households	229	7.5 (6.6–8.5)		246	8.1 (7.1–9.2)					247	8.5 (7.6–9.5)	
	Landline (RDD) sample	181	7.2 (6.2–8.3)	−0.009	195	8.3 (7.1–9.6)	0.003				173	8.3 (7.4–9.4)	−0.033
	Directory-listed sample	133	7.1 (6.0–8.5)	−0.021	148	8.6 (7.1–10.3)	0.030				117	7.9 (6.7–9.4)	−0.077
Current asthma	All households	416	13.6 (12.2–15.3)		384	12.7 (11.4–14.0)							
	Landline (RDD) sample	335	13.3 (11.7–15.2)	−0.015	297	12.6 (11.1–14.2)	−0.002						
	Directory-listed sample	246	13.1 (11.3–15.2)	−0.061	220	12.8 (10.9–15.0)	−0.014						
Arthritis	All households	653	21.4 (19.9–23.1)		727	24.0 (22.3–25.7)		656	21.5 (19.7–23.3)		640	22.0 (20.3–23.8)	
	Landline (RDD) sample	529	21.1 (19.5–22.8)	−0.025	554	23.5 (21.6–25.4)	−0.031	495	21.2 (19.3–23.2)	0.009	464	22.3 (20.4–24.4)	0.019
	Directory-listed sample	387	20.7 (18.9–22.6)	−0.083	407	23.7 (21.4–26.1)	−0.018	346	20.7 (18.5–23.2)	−0.046	324	22.0 (19.7–24.4)	−0.016
Mental health condition	All households	330	10.8 (9.6–12.2)		359	11.8 (10.7–13.1)		297	9.7 (8.7–10.8)		384	13.2 (11.8–14.7)	
	Landline (RDD) sample	250	10.0 (8.6–11.5)	−0.100	275	11.6 (10.3–13.1)	−0.046	222	9.5 (8.2–10.9)	−0.025	256	12.3 (10.7–14.1)	−0.091
	Directory-listed sample	167	8.9 (7.4–10.7)	−0.242	221	12.9 (11.0–15.0)	0.056	150	9.0 (7.6–10.6)	−0.102	172	11.6 (9.4–14.3)	−0.141
	Health - related risk factors												
Current smoker	All households	614	20.2 (18.3–22.1)		529	17.4 (15.8–19.2)		501	16.4 (14.8–18.2)		552	19.0 (16.6–21.6)	
	Landline (RDD) sample	429	17.1 (15.2–19.2)	−0.136	343	14.5 (12.8–16.5)	−0.191	304	13.0 (11.4–14.9)	−0.174	330	15.9 (13.6–18.6)	−0.138
	Directory-listed sample	316	16.9 (14.7–19.3)	−0.129	223	13.0 (10.9–15.4)	−0.313	210	12.6 (10.8–14.7)	−0.181	202	13.7 (11.6–16.1)	−0.244
Obese	All households	611	22.1 (20.4–24.0)		612	22.7 (20.9–24.6)		621	23.4 (21.5–25.4)		603	23.1 (20.7–25.8)	
	Landline (RDD) sample	511	22.6 (20.7–24.6)	0.036	491	23.3 (21.2–25.5)	0.013	474	23.5 (21.4–25.8)	−0.020	454	24.3 (21.8–27.0)	0.078
	Directory-listed sample	379	22.5 (20.3–25.0)	−0.002	359	23.8 (21.2–26.6)	0.059	329	22.7 (20.1–25.5)	−0.050	329	24.6 (21.6–27.9)	0.079

Note: *RCB* relative coverage bias, *Landline (RDD) sample* households that had a landline connection (mobile-only households excluded); *Directory-listed sample* households with either a landline or mobile telephone number listed in the White Pages

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estimates because of the groups that are excluded from the sampling frames.

This study is important because it quantifies the potential biases from the various landline-based telephone sampling frames used in Australia and the groups that are potentially excluded. Even though the data are limited to South Australia, the conclusions may be generalizable to the Australian population. This study is unique since the same questions have been asked annually for eight years and, using the face-to-face methodology in which all types of households are included (mobile-only, landline-only or both), it had the ability to examine, over time, the prevalence estimates of various health indicators by telephone status. Very few studies like this are known to exist nationally [14] and internationally [15, 30] and even fewer examine the assessment on health indicators [30].

The trends and demographic differences found in this study are similar to national and international studies [11, 14, 15, 30, 42, 43] and support findings from our previous research [26]. Our estimate of mobile-only households in 2012 (23.9 %) was higher than the estimate reported by the Australian Communication and Media Authority (19 %) [14]; the proportion of households with a landline telephone in 2010 was 82.5 % which was slightly higher than the 80.3 % estimate from the 2010–11 Australian Health Survey (AHS); and our estimate of 68.7 % of landline telephone numbers listed in the telephone directory was slightly lower than the 70.1 % from the AHS 2010–11 survey [44]. Between 2006 and 2008 the trend of mobile-only households remained low, however since 2009, the trend has steadily increased, following international patterns [30]. Similarly for landline ownership, up to 2011 the proportion was over 80 %, however, this has steadily decreased to 71.9 % in 2013. These changes are mainly due to the increasing popularity of greater flexibility and affordability offered by mobile technology. People are using landlines less frequently because they are able to have a single device with multiple communication and media services, which is less expensive than having a landline connection [13].

In our previous study [26], nearly 10 % of the population in 2008 lived in mobile-only households, and we showed that with appropriate weighting, the sampling methodology used for telephone surveys produced reliable health estimates with the exception of smoking prevalence in South Australia being underestimated. In contrast, with more recent data and up-to-date analyses, this study has estimated that close to 30 % of the Australian population now live in mobile-only households and these analyses have demonstrated the impact of the vast changes in the telecommunication over the eight year study period on the coverage of the sampling frames. Excluding a distinct subpopulation from the landline sampling frames, namely mobile-only households, resulted in under- or over-estimation in some health estimates, although with appropriate weighting most health estimates (except smoking and mental health) were very similar to the overall population. Even though the results in the health estimates (absolute differences and RCB values) between the overall population and the two hypothetical landline sample groups showed no clear pattern over time, the results do highlight that for specific health indicators, such as current smokers and mental health, the direction of the bias was consistently under-estimated for both RDD and directory-listed landline hypothetical samples. The other conditions (diabetes, current asthma, arthritis and obesity) had little absolute differences in health estimates and an inconsistent pattern, but relatively low, RCB values over time, which may suggest that the differences could be due to the random nature of the sample or other sampling errors. Our findings for current smokers, asthma and obesity are similar to other USA studies [30] using similar methodology, and are consistent with studies using dual-frame telephone surveys for mental health [45], current smoking [30, 46, 47], asthma [47], and obesity [30]. This suggests that perhaps an alternative sampling, surveying or statistical methodological approach may need to be considered to include groups of the population to remove the coverage biases in landline-based sampling frames.

Many studies have explored various methods to include the mobile-only group into chronic disease and risk factor surveillance systems [12, 48]. The favoured method is an over-lapping dual-frame design which involves two independent samples: a sample of mobile telephones and a landline-based sample [34, 35, 46, 49]. These studies showed an improvement in the representativeness, in particular for men, the younger and middle age groups, and people who were never married. However, obtaining a sample of mobile telephone numbers does have drawbacks, including low response rates and two to four times the costs of landline-based samples [34]. More importantly, the mobile sample that is currently available and used in Australia is of randomly generated mobile telephone numbers with no geographical marker. From a South Australian perspective, only 8 % of all mobile telephone numbers in Australia were estimated to be owned by South Australians [34, 35, 46, 49], which is almost the same proportion of the state's population (7.4 %). This means a much larger initial sample is required for screening, and with the additional problem of low response rate, the feasibility of including mobile numbers using these methods in a chronic disease and behavioural risk factor surveillance system in South Australia would be costly. Even though 98 % of South Australians have a mobile telephone and it is perceived that people can be reached anytime, it does not mean that they are willing or able to use it to complete a survey. Receiving

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mobile telephone calls can happen at unpredictable moments when it is not suitable for the owner to respond, such as driving (safety issue), travelling overseas (which can incur a large cost to the researcher or participant), or during a meeting or in a restaurant (privacy issue); all have an impact on response rates [43].

Mixed-mode methods have also been suggested as a way to complement the traditional landline telephone survey by combining face-to-face, mail, and internet surveys [50]. These alternative modes introduce other methodological issues and the design of each mode need to be taken into consideration. The questionnaire design for CATI surveys, for example, complicated skips patterns or data range checks, needs to be careful considered in other modes such as mail survey [51]. Face-to-face, mail and internet survey can have the option of longer worded questions, explanations, and visual or prompt cards which is not recommended or possible with CATI surveys. Therefore, the wording of the questions in telephone surveys needs to be clear, concise and short [52]. Operational differences can have an impact on how the questions are answered. Telephone surveys are mainly interviewer administered whereas mail or internet surveys are self-administered which can lead to different responses [50, 51]. In telephone surveys, the interviewer has control over who is the selected respondent within the household whereby in the mail or internet surveys any member of the household determines who is the selected [12]. The level of privacy can vary by survey modes which is high with mail or internet surveys compared to moderate level of privacy with telephone (others listening in, or answering sensitive questions) [53]. Mail surveys require a longer data collection period compared to the allocated time period for telephone surveys. In an attempt to include respondents from mobile-only households, a study examined the possibly of using two modes, telephone and mail, with a single database that consisted of residential addresses. However, they found that the groups that were under-represented in telephone surveys were also under-represented in the mail surveys [48]. Another consideration for surveillance systems that used the telephone to collect data, is the challenge of how to incorporate alternative modes but still maintain the timeliness, flexibility, low non-response and low cost of the system [12]. Other methodological studies have used statistical approaches such as alternative weighting strategies, such as raked weights, which incorporate a wider range of sociodemographic variables, can improve the health estimates and are more in line with face-to-face surveys [54–56].

The study design used in this research is robust due to the large representative state-wide samples used and is unique in that the data were collected over eight years using the same or similar questions, and by one organisation, thus minimising interviewer biases. These data are also very recent and it is one of the few face-to-face studies conducted in Australia and worldwide that included questions on landline and mobile telephone status that also had questions on health status and behavioural risk factors [30] so the biases in health estimates can be assessed. However the results could be biased due to the moderately acceptable response rates (median = 59.3 %) which is following the trends observed interstate and overseas. This study only analysed a few health-related variables and additional questions such as health service usage, quality-of-life or alcohol consumption would have provided a more comprehensive description of telephone sampling biases.

Conclusion

Telephone surveys have become a standard and accepted method of collecting health information in Australia and are widely used to monitor chronic disease and behavioural risk factors. Such surveillance systems provide evidence to inform interventions and service planning with the aim of reducing the impact of chronic diseases and their associated costs to the health system. Analyses like those presented here are important to demonstrate that the health estimates obtained are not biased due to sampling methodology. This study has shown that the proportion of mobile-only households is increasing and this does not appear to have reached a plateau. This corresponds with the decrease in landline telephone coverage. Even with appropriately weighted data, using landline-based sampling frames in Australia are potentially biased for some health indicators. This implies that the landline sampling frames that are currently used in most Australian chronic disease and risk factor surveillance systems (RDD landline or directory-listed telephone numbers) are not sufficient on their own because of the exclusion of the mobile-only households. Other methodologies need to be considered for small states like South Australia that are timely, cost-effective and efficient.

Availability of data and materials

The Health Omnibus Survey (HOS) is a user-pay survey in which various organisations pay for their questions to be included in the surveys. Because of this, the authors of this study do not own all of the HOS data and permission had to be sought from each owner, therefore data are not publicly available.

Ethical statement

Ethical approvals were obtained from the Research Ethics Committees of The University of Adelaide and the South Australian Department of Health. Participation in the study is voluntary. Verbal informed consent was obtained from participants at the start of the interview.

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Prior to contact by the interviewers, a primary approach letter was sent to the household informing the household of the purpose of the survey including a pamphlet listing the organisations involved in the survey, confidentiality and privacy assurance, that participation is voluntary, and a contact number for queries. Upon initial contact, the interviewers repeat the purpose of the survey as well as the expected length of time to complete the interview.

Consent for publication
Not applicable.

Additional file

Additional file 1: Table S1. Sample socio-demographic profile by survey year, 15 years and over. **Table S2.** Proportion of respondents living in households with a landline connection (RDD) by socio-demographic variables, 15 years and over. **Table S3.** Proportion of respondents living in households with at least one mobile telephone by socio-demographic variables, 15 years and over. **Table S4.** Proportion of respondents living in households with a directory-listed telephone number (EWP) by socio-demographic variables, 15 years and over. (DOCX 107 kb)

Abbreviations
ABS: Australian Bureau of Statistics; BMI: body mass index; CATI: computer assisted telephone interviewing; CD: collector districts; EWP: electronic white pages; HOS: Health Omnibus Survey; IRSD: index of relative social disadvantage; RCB: relative coverage bias; RDD: random digit dialling; SA1: Statistical Areas Level 1; SEIFA: Socio-Economic Indexes for Areas; SPSS: Statistical Package for Social Sciences; VoIP: Voice over Internet Protocol.

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Practice of Epidemiology

Health Estimates Using Survey Raked-Weighting Techniques in an Australian Population Health Surveillance System

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A challenge for population health surveillance systems using telephone methodologies is to maintain representative estimates as response rates decrease. Raked weighting, rather than conventional poststratification methodologies, has been developed to improve representativeness of estimates produced from telephone-based surveillance systems by incorporating a wider range of sociodemographic variables using an iterative proportional fitting process. This study examines this alternative weighting methodology with the monthly South Australian population health surveillance system report of randomly selected people of all ages in 2013 ($n = 7,193$) using computer-assisted telephone interviewing. Poststratification weighting used age groups, sex, and area of residence. Raked weights included an additional 6 variables: dwelling status, number of people in household, country of birth, marital status, educational level, and highest employment status. Most prevalence estimates (e.g., diabetes and asthma) did not change when raked weights were applied. Estimates that changed by at least 2 percentage points (e.g., tobacco smoking and mental health conditions) were associated with socioeconomic circumstances, such as dwelling status, which were included in the raked-weighting methodology. Raking methodology has overcome, to some extent, nonresponse bias associated with the sampling methodology by incorporating lower socioeconomic groups and those who are routinely not participating in population surveys into the weighting formula.

health estimates; nonresponse bias; poststratification weighting; public health surveillance; raked weights; telephone surveys

Abbreviations: AHS, Australian Health Survey; BRFSS, Behavioral Risk Factor Surveillance System; HOS, Health Omnibus Survey; SAMSS, South Australian Monitoring and Surveillance System.

Chronic disease and behavioral risk factor surveillance systems have been established in many countries, including Australia (1–6), as a response to the rising prevalence of chronic diseases and the contributing preventable lifestyle factors (7, 8). To be effective and valuable, the system must be quick, relatively inexpensive, flexible, representative, population based, continuous, and with independent samples drawn at each time period (9, 10). Because of these requirements, many systems use telephone surveys based on computer-assisted telephone-interviewing technology (1–3, 5, 11–16).

In the last decade, telephone surveys have undergone many changes because of nonresponse and noncoverage (15, 17, 18), with a resultant potential loss in the precision of survey estimates. *Nonresponse* can be defined as "the failure to obtain a valid response from a sampled unit" (18, p. 329) and is usually measured by response rates (19). Response rates have been declining in population surveys of all modes: face-to-face, mail, Internet, and telephone surveys (20). Reasons for falling response rates are the increasing proportion of people not willing to participate in surveys of any kind and the inability to establish contact with potential participants (18, 20). *Noncoverage* can be defined as "the proportion of the target population not covered by the sampling frame" (21, p. 55). The majority of telephone surveys in Australia rely

on sampling frames that consist mainly of landline telephone numbers (2, 3, 14, 22–24). Over the past decade, nationally and internationally, society has moved away from the traditional landline telephones to flexible communications, such as the mobile telephone (15, 17, 23, 25–29). This transition is associated with an increase in mobile-only households. In Australia, this has implications for telephone surveys because of the difficultly of obtaining a sample of mobile telephone numbers with a geographical location, such as postcode or state. Australian data from 2011 have estimated that 22% of households are mobile only, which is an increase of over 75% since 2006 (5.2%) (25). More importantly, this group is not uniformly distributed in the population (23, 30). These mobile-only households result in specific groups being excluded from the traditional sampling frames used for telephone surveys. These include younger people and people who are unemployed, rent their housing, and reside in low socioeconomic areas (15, 17, 23–29, 31, 32). This is compounded in most countries by the difficulty in obtaining a cost-effective and efficient sampling frame (23, 26) and has led to the declining representativeness of surveillance systems based on telephone survey sampling methodology (16, 17). Recent debates have questioned the value of representativeness in epidemiologic study designs, particularly those focused on examining the causal effect of exposures or interventions on outcomes (33). Descriptive studies, where the aim is to estimate the occurrence of a disease or risk factor in a given population, however, are the case for which representativeness is universally supported (34–37).

Various statistical methods have been developed to address and improve the representativeness of the estimates produced from telephone-based surveillance systems due to nonresponse. A common statistical approach is to weight the survey data on the basis of the sociodemographic variables that are under- or overrepresented in the sample, such that the proportion of the cases in the sample is adjusted to the population proportion as in the census (15). Weighting approaches can be seen as a form of imputation, where the weight of the nonresponders is distributed to other similar respondents (38). These imputation methods are model based and are described in detail elsewhere (39). Weighting is a technique for adjusting the unit record survey such that the data structure is made similar to the population structure in terms of sociodemographic indicators, such as, age and sex, so that inferences can be made. Weighting by the appropriate variables allows point and parameter estimates generated from survey data (e.g., means, proportions, and regression coefficients) to be unbiased population estimates, and it involves statistically increasing or decreasing the numbers of cases (17, 21). This means that a weighting value is calculated for each individual who participates in a survey, and that weighting value indicates how much the individual's response will count in a statistical procedure. Weighting values are often represented as a fraction, they have a mean value of 1.0, and the sum of the weighting values usually equals the sample size, is always positive, and is non-0 (e.g., 1.35, 0.75). To illustrate, a participant with a weighting value of 2.0 means that his/her response is counted 2 times compared with a participant with a weighting value of 0.5, which means that his/her response is half a count. Using diabetes prevalence as an example,

researchers have found that general population surveys in Australia usually have a higher proportion of older people than younger people participating. Unweighted data indicate that 12.0% of the sample has diabetes, but this estimate is an overestimation because we have a higher proportion of older people. With weighted data, older respondents have weighting values less than 1.0 and younger respondents have weighting values greater than 1.0; this results in a diabetes prevalence of 7.7% that is more reflective of the population.

The weights are developed in a series of stages. One is to calculate the base weight (40), which is to take into account the complex sampling design and to adjust the data according to the different selection probabilities and the complex sampling design. For example, only 1 eligible person is selected at random within a household to participate (21). The other part is cell weighting or poststratification adjustments (the focus of this paper) that modify the survey data by particular characteristics so that the proportion of cases in the sample is adjusted to the population proportion, such as census data. The standard *poststratification* weighting (or cell weighting) method adjusts the sample data by creating a cross-classification of categorical variables (e.g., age groups × sex × area of residence × marital status × income) and matches the proportions to population data. However, this method has limitations as each addition of a variable in the cross-tabulations can result in smaller or empty cell sizes that can result in unstable weights. Therefore, only a few variables are usually included, typically, age group, sex, and area of residence.

The US Behavioral Risk Factor Surveillance System (BRFSS) has implemented a statistical technique called *raked weights* or *raking* to address the problem with the *poststratification* weighting method (12, 41). Raking adjusts the sample data 1 variable at a time by using an iterative proportional fitting process (42, 43). Changes in some BRFSS health estimates, including prevalence of current smokers, no physical activity, or perceived health as fair or poor, have resulted when raked weights were applied (12, 42, 44). However, they have also found that the prevalence of other health conditions, such as diabetes and coronary heart disease, remained the same.

The raking iterative process can be explained by using the following example with 2 variables: age (i.e., 7 age group categories) and sex (2 categories). Starting with age groups, each case is multiplied by the ratio of the population total to the weighted sample total for each age group category. This will result in the age group category totals of the adjusted weighted data agreeing with the population totals. However, the weighted category totals for the sex variable do not agree with its corresponding population category totals. The next step is to take the sex variable and multiply each case by the ratio of the population total to the weighted sample total for each sex group category. Now the new calculated weighted category totals for sex will agree with the population totals for sex. However, the weighted category totals for the age group variable do not agree with its corresponding population category totals, and the calculation is repeated, until the weighted category totals for both age groups and sex agree with the corresponding population category totals.

The challenge for chronic disease and behavioral risk factor surveillance systems utilizing the telephone in Australia and similar countries is to ensure that the methodology is effective

and efficient in obtaining and providing representative and reliable population data. This raking weighting method has not been applied in Australia but could potentially reduce bias in the estimates from Australian chronic disease and risk factor surveillance systems. It is not known if major differences across weighting methods found in the BRFSS would apply in Australia (with higher responses rates and different ethnicity and socioeconomic distributions). The main objective of this paper is to apply the raking methodology to data from an Australian population health surveillance system and to examine the impact on the estimates produced by use of traditional (cell weighting) and raked weights.

METHODS

Survey design and sample selection

Data for this study were collected by using the South Australian Monitoring and Surveillance System (SAMSS) in 2013. SAMSS is a telephone-monitoring system designed to monitor, over time, the health conditions, risk factors, and other health service issues in South Australia (1). Approximately 600 randomly selected interviews were conducted for all ages each month. Households in South Australia with a telephone connected and listed in the telephone directory were eligible. A letter introducing the survey was sent to the selected household. Within each household, the person with the most recent birthday was chosen for interview. There were no replacements for nonrespondents. Up to 10 callbacks were made to the household to interview the selected person. Interviews were conducted by trained health interviewers via a computer-assisted telephone-interviewing system. Ethical approvals were obtained from the human research ethics committees of The University of Adelaide and the South Australia Department of Health. Participants gave verbal informed consent to participate in the telephone interview. A total of 7,193 interviews were conducted in 2013 with a 61.7% response rate.

Sociodemographic variables used for raked-weighting methodology

The population source was the 5-yearly Australian Bureau of Statistics 2011 Census, using TableBuilder Pro (45), which allowed some flexibility in constructing summary data to match with SAMSS demographic questions. Nine sociodemographic variables to be incorporated into the raked-weight methodology were ascertained as suitable and are shown in Table 1. Sociodemographic variables were considered if they had a strong association with various chronic disease and behavioral risk factors or were strongly related to nonresponse or noncoverage. Sociodemographic variables with categories having less than 5% in the sample were not considered, such as Aboriginal/Torres Strait Islander status. Categories were collapsed, or variables were excluded if there was a high proportion of missing data or difficulties in harmonizing the categories or variables between SAMSS and the census because of wording differences.

Sociodemographic variables used for poststratification weighting

The variables used for poststratification weighting were age groups, sex, and area of residence, as described for raked weights (Table 1).

Outcome variables

For respondents aged 16 years or more, self-reported health conditions included overall health status, diabetes, cardiovascular disease (heart attack, angina, heart disease, and/or stroke), arthritis, current asthma (46), chronic obstructive pulmonary disease, and osteoporosis. Having a chronic condition included diabetes, current asthma, cardiovascular disease, arthritis, or osteoporosis. Psychological distress used 10 questions from the Kessler 10 screening scale (47) scored to a single scaled

Table 1. Variables Used in Weighting (Poststratification and Raking)

Variable	Categories	Poststratification Weights	Raked Weights
Sex	Male, female	Yes	Yes
Age groups	0–9, 10–15, 16–34, 35–44, 45–54, 55–64, 65–74, ≥75 years	Yes	Yes
Area of residence	Metropolitan Adelaide, rural or remote areas	Yes	Yes
Country of birth	Australia, United Kingdom, Europe, other	No	Yes
Dwelling status	Renting, other (owned or being purchased, other)	No	Yes
Marital status (16 years or more)	Married or living with partner, other (widowed, separated, divorced, never married)	No	Yes
Educational level (16 years or more)	Bachelor's degree or higher, other (none to some high school, trade, certificate, diploma)	No	Yes
Employment status (16 years or more)	Full-time employed, part-time employed, unemployed, other (home duties, student, retired, unable to work)	No	Yes
No. of people in the household (including children)	1, 2, 3, 4 or more	No	Yes

Table 2. Demographic Profile of the South Australian 2011 Census and Estimates for All Age Groups From the 2013 South Australian Monitoring and Surveillance System Using Unweighted Data and Data With Poststratified Weights and Fully Raked Weights

		2013 SAMSS (*n* = 7,193)					
Sociodemographic Variable	2011 Census (*n* = 1.60 million), %	Unweighted		Poststratification Weights[a]		Fully Raked Weights[b]	
		%	% Difference[c]	%	% Difference[c]	%	% Difference[c]
Age groups, years							
0–9	11.9	7.2	−4.70	11.9	0.00	11.9	0.00
10–15	7.4	5.7	−1.70	7.4	0.00	7.4	0.00
16–34	24.4	10.5	−13.90	24.4	0.00	24.4	0.00
35–44	13.5	5.9	−7.70	13.5	0.00	13.6	0.00
45–54	14.1	12.2	−1.89	14.1	0.00	14.1	0.00
55–64	12.5	20.1	7.65	12.5	0.00	12.5	0.00
65–74	8.3	21.4	13.05	8.3	0.00	8.3	0.00
≥75	7.8	17.0	9.21	7.8	0.00	7.8	0.00
Sex							
Male	49.3	42.1	−7.17	49.3	0.00	49.3	0.00
Female	50.7	57.9	7.17	50.7	0.00	50.7	0.00
Area of residence							
Metropolitan Adelaide	71.6	63.7	−7.92	71.6	0.00	71.6	0.00
Rural or remote areas	28.4	36.3	7.92	28.4	0.00	28.4	0.00
Dwelling status							
Owned or being purchased, other	72.2	86.5	14.24	85.4	13.16	72.2	0.01
Rent	27.8	13.5	−14.24	14.6	−13.16	27.8	−0.01
Country of birth							
Australia	76.9	78.7	1.79	82.9	5.99	76.9	0.00
United Kingdom	8.3	11.5	3.21	7.5	−0.76	8.3	0.00
Europe	5.4	5.6	0.22	4.1	−1.26	5.4	0.00
Other	9.5	4.2	−5.22	5.5	−3.96	9.5	0.00

Table continues

item, where respondents with high scores of 22–50 were categorized as having psychological distress (48). Having a current mental health condition meant a diagnosis of and/or treatment for anxiety, depression, a stress-related problem, or another mental health problem. Suicidal ideation used 4 items from the 28-item General Health Questionnaire (49) that produced a score ranging from 0 to 4, where a score of 1 or more indicated suicidal ideation (50).

For respondents aged 16 years or more, self-reported health-related risk factors included current or receiving treatment for high blood pressure and cholesterol, sufficient physical activity (51), smoking status, lifetime risk of harm to health from alcohol consumption (52), and overweight or obese status (53) (as determined by a body mass index (self-reported weight in kilograms divided by height in meters squared) ≥25.0). Recommended amounts of fruit and vegetables for people aged 18 years or more were defined as having at least 5 daily servings of vegetables and 2 daily servings of fruit (54). Recommended daily servings of fruit (1–2 servings) and vegetables (2.5–5.5 servings) for children aged 2–17 years varied according to age (54).

Food insecurity was defined as households running out of food or could not afford to buy more in the last 12 months. Respondents were asked the number of times they had takeaway (carryout) food per week. The family money situation was divided into 2 groups: unable to save (spending more money than getting, having just enough to get through to the next pay, having some money left over each week but just spending it) and able to save (can save a bit occasionally or a lot).

Survey weight adjustment methods

Raking is an iterative process, and usually 1 variable at a time is applied to the proportional adjustment of the weights. The data are gradually adjusted to fit to specific characteristics so the survey variables (or survey margin totals) match with population variables (or control totals) such as census data (42, 43, 55). The iterative process is finalized when the differences between all the categories' proportions from the census data and raked weights from the survey data margin are convergent within an acceptable predefined tolerance

Table 2. Continued

Sociodemographic Variable	2011 Census (*n* = 1.60 million), %	2013 SAMSS (*n* = 7,193)					
		Unweighted		Poststratification Weights[a]		Fully Raked Weights[b]	
		%	% Difference[c]	%	% Difference[c]	%	% Difference[c]
Marital status							
Married/living with partner	43.2	49.8	6.62	47.7	4.52	43.1	−0.04
Other	37.6	37.3	−0.26	33.0	−4.56	37.6	0.00
Under 16 years	19.2	12.9	−6.36	19.3	0.03	19.3	0.04
Educational level							
None to some high school, trade, certificate, diploma	69.8	70.8	1.01	63.9	−5.90	69.8	−0.03
Degree or higher	11.0	16.3	5.35	16.8	5.86	11.0	−0.01
Under 16 years	19.2	12.9	−6.36	19.3	0.03	19.3	0.04
Employment status							
Full-time employed	31.2	21.4	−9.74	28.1	−3.04	31.2	0.01
Part-time employed	17.1	14.4	−2.73	16.1	−0.96	17.1	0.01
Unemployed	2.9	1.5	−1.39	1.9	−0.96	2.8	−0.09
Economically inactive (home duties, student, retired, unable to work because of illness)	29.6	49.9	20.22	34.6	4.93	29.7	0.02
Under 16 years	19.2	12.9	−6.36	19.3	0.03	19.3	0.04
No. of people in the household (including children)							
1	26.4	25.9	−0.49	9.4	−17.07	26.4	−0.04
2	34.7	41.1	6.43	27.7	−6.97	34.7	−0.01
3	15.5	12.2	−3.31	18.0	2.50	15.6	0.02
≥4	23.4	20.7	−2.62	44.9	21.55	23.4	0.03

Abbeviation: SAMSS, South Australian Monitoring and Surveillance System.

[a] Three variables included in poststratification weights (age, sex, area of residence).

[b] All 9 variables included in raked weights (age, sex, area of residence, dwelling status, country of birth, marital status, educational level, employment status, and number of people in household).

[c] Percentage differences are between the 2011 Census and SAMSS.

limit of 0.025 (43, 56). For example, the raked weighted proportion of males from the survey data (49.3%) is the same as the census proportion of males (49.3%). Alternatively, the process is terminated once a predefined set number of iterations has been reached, for example, 60 (43). As recommended by Izrael et al. (43) and Battaglia et al. (55, 57), raked weights that had extremely high or low weight values in our sample were trimmed to reduce their impact on the variance of the estimates by recoding weights larger or smaller than the median weight plus 6 times the interquartile range of the weight to these limits. A raking program, using SPSS version 20.0 syntax code (IBM SPSS Statistics for Windows software; IBM Corp., Armonk, New York), to calculate the raked weights was developed, and the base design weight (the number of people living in the household and the number of telephone listings in the telephone directory) was included in the calculation. User-written programs on raked weights have been developed and are available for general use in SPSS (*SPSS_RAKE*) and Stata (*ipfraking*) statistical software (StataCorp LP, College Station, Texas).

Poststratification weighting of SAMSS used area of residence (metropolitan Adelaide, rural or remote areas), 10-year age groups, sex, and probability of selection in the household to the most recent estimated residential population or census data. Probability of selection in the household is based on the number of people living in the household and the number of telephone listings in the telephone directory.

A detailed explanation of poststratification and raked weights is in the Appendix.

Statistical analyses

Data analysis was conducted by using SPSS version 20.0. Prevalence estimates were presented for self-reported fair or poor health, diabetes, current smokers, and current high blood pressure by using poststratification weights and raked weights. These 4 variables were used to demonstrate the impact on the estimates by use of different sociodemographic variables, besides age, sex, and area of residence, in raked weights. For other selected health indicators, the differences between

Table 3. Effect of Including Different Sociodemographic Variables in the Raked Weights on Health Prevalence Estimates for Persons Aged 16 Years or More, South Australian Monitoring and Surveillance System, 2013

Variables Used in Poststratified and Raked Weights	Fair/Poor Overall Health		Diabetes		Current Smokers		Current High Blood Pressure	
	Prevalence, %[a]	95% CI	Prevalence, %	95% CI	Prevalence, %	95% CI	Prevalence, %	95% CI
Unweighted	20.3	19.3, 21.3	12.0	11.3, 12.9	11.5	10.8, 12.4	34.9	33.7, 36.0
Poststratification weight	15.3	14.4, 16.3	7.7	7.1, 8.4	12.8	11.9, 13.6	20.7	19.6, 21.7
Raked weights calculated by using								
Age, sex, area of residence	15.5	14.5, 16.4	7.6	7.0, 8.3	12.7	11.9, 13.6	20.7	19.6, 21.7
Age, sex, area of residence, dwelling status	16.5	15.6, 17.5	8.1	7.4, 8.8	14.4	13.5, 15.3	21.0	20.0, 22.1
Age, sex, area of residence, country of birth	15.4	14.4, 16.3	7.7	7.0, 8.4	12.5	11.7, 13.4	20.6	19.6, 21.7
Age, sex, area of residence, marital status	15.9	14.9, 16.8	7.7	7.1, 8.5	13.3	12.4, 14.2	20.8	19.8, 21.9
Age, sex, area of residence, educational attainment	15.8	14.8, 16.7	7.8	7.2, 8.6	13.6	12.7, 14.5	21.2	20.1, 22.2
Age, sex, area of residence, employment status	14.8	13.9, 15.8	7.5	6.8, 8.2	12.9	12.1, 13.8	20.3	19.3, 21.3
Age, sex, area of residence, no. of people in household	16.7	15.7, 17.6	8.2	7.5, 8.9	14.7	13.8, 15.6	21.2	20.2, 22.3
Age, sex, area of residence, dwelling status, country of birth	16.4	15.4, 17.3	8.1	7.4, 8.8	14.2	13.3, 15.1	21.1	20.1, 22.2
Age, sex, area of residence, dwelling status, country of birth, marital status	16.7	15.7, 17.6	8.2	7.5, 8.9	14.7	13.8, 15.6	21.2	20.2, 22.3
Age, sex, area of residence, dwelling status, country of birth, marital status, educational attainment	17.1	16.2, 18.1	8.3	7.6, 9.0	15.5	14.6, 16.5	21.8	20.7, 22.9
Age, sex, area of residence, dwelling status, country of birth, marital status, educational attainment, employment status	16.0	15.1, 17.0	8.0	7.3, 8.7	15.6	14.7, 16.6	21.3	20.2, 22.3
Fully raked (9 variables): age, sex, area of residence, dwelling status, country of birth, marital status, educational level, employment status, no. of people in household	18.1	17.1, 19.1	8.4	7.8, 9.2	16.3	15.4, 17.3	21.6	20.6, 22.7

Abbreviation: CI, confidence interval.

[a] All prevalence values are estimates.

poststratification weights and the fully raked weights were calculated. The raked-weight methodology was assessed by comparing the raked estimates with 2 external data sources: the 2013 Health Omnibus Survey (HOS) (58) and the 2011–

2012 Australian Health Survey (59) (AHS) where the questions were the same or very similar. HOS is an annual face-to-face household survey of South Australians with a 57.6% response rate, and the AHS is a face-to-face survey of all

Table 4. Prevalence Estimates, Differences, and Percentage Change of Various Health Conditions, Behavioral Health Risk Factors, and Other Health-Related Issues Between Poststratified Weights and Raked Weights, South Australian Monitoring and Surveillance System, 2013

Variable	Poststratification Weights		Fully Raked Weights		Differences, %	Percentage Change
	Prevalence, %[a]	95% CI	Prevalence, %[a]	95% CI		
Health conditions						
Current asthma (children)	13.8	12.0, 15.8	14.1	12.3, 16.2	0.3	2.2
At least 1 chronic condition	38.3	37.1, 39.6	40.3	39.0, 41.6	2.0	5.2
Cardiovascular disease	7.4	6.8, 8.1	7.8	7.2, 8.6	0.4	5.4
Current asthma (adults)	13.2	12.3, 14.1	14.0	13.1, 14.9	0.8	6.1
Osteoporosis	4.4	3.9, 5.0	4.7	4.2, 5.3	0.3	6.8
Chronic obstructive pulmonary disease	3.4	3.0, 3.9	3.7	3.3, 4.3	0.3	8.8
Diabetes	7.7	7.1, 8.4	8.4	7.8, 9.2	0.7	9.1
Arthritis	20.6	19.5, 21.6	23.0	22.0, 24.1	2.4	11.7
Self-reported fair or poor	15.3	14.4, 16.3	18.1	17.1, 19.1	2.8	18.3
Current diagnosed mental health condition	16.6	15.7, 17.6	20.0	19.0, 21.1	3.4	20.5
Psychological distress (Kessler 10)	8.8	8.1, 9.6	11.3	10.5, 12.1	2.5	28.4
Suicidal ideation	3.6	3.1, 4.1	5.1	4.6, 5.7	1.5	41.7
Behavioral health risk factors						
Sufficient servings of fruit per day (children)	67.1	64.8, 69.3	67.8	65.3, 70.2	0.7	1.0
Lifetime risk of harm due to alcohol consumption	33.1	31.9, 34.3	32.7	31.5, 33.9	−0.4	−1.2
Sufficient physical activity	42.7	41.4, 44.0	40.9	39.7, 42.2	−1.8	−4.2
Overweight/obesity	59.0	57.6, 60.3	61.5	60.2, 62.8	2.5	4.2
Sufficient servings of fruit per day (adults)	44.3	43.0, 45.6	42.4	41.1, 43.7	−1.9	−4.3
Current high blood pressure	20.7	19.6, 21.7	21.6	20.6, 22.7	0.9	4.3
Current high cholesterol	16.9	16.0, 17.9	17.7	16.8, 18.7	0.8	4.7
Sufficient servings of vegetables per day (adults)	11.7	10.9, 12.6	11.1	10.3, 11.9	−0.6	−5.1
Having at least 1 day off from usual activities due to health	13.7	12.1, 15.4	14.5	12.7, 16.4	0.8	5.8
Sufficient servings of vegetables per day (children)	14.1	13.2, 15.0	16.5	15.6, 17.5	2.4	17.0
Current smoker	12.8	11.9, 13.6	16.3	15.4, 17.3	3.5	27.3
Having takeaway (carryout) 3 or more times per week	1.9	1.6, 2.3	2.5	2.2, 2.9	0.6	31.6
Smoking in home occasionally or all the time	4.7	4.0, 5.4	6.5	5.7, 7.3	1.8	38.3
Food supply insecure	3.2	2.8, 3.7	6.1	5.6, 6.7	2.9	90.6
Other health-related issues (financial situation, unable to save)	28.2	27.1, 29.2	31.6	30.5, 32.7	3.4	12.1

Abbreviation: CI, confidence interval.

[a] All prevalence values are estimates.

Australians with an 85.9% response rate. Both of these surveys use poststratification methods to calculate their survey weights and include mobile-only households in their sampling frame.

RESULTS

When compared with census estimates, the unweighted age distribution of SAMSS had a higher proportion of older people and a lower proportion of younger people, as well as a higher proportion of females (Table 2). SAMSS had a lower proportion of people who rent, were employed, or were unemployed and a higher proportion who were born in Australia or the United Kingdom, married or living with a partner, and economically inactive. Poststratification weighting reduced the differences for dwelling status, employment status, and marital status.

Table 3 demonstrates the effect on the prevalence estimates for fair or poor health, diabetes, current smokers, and current high blood pressure of including the 9 variables, cumulatively, in the raked weights. All 4 of the prevalence estimates changed, as expected, when the typical age, sex, and area of residence variables were included in the raked and poststratification weights. When the other sociodemographics were added, individually or as a whole, the prevalence of diabetes

and current high blood pressure changed slightly. The prevalence of self-reported fair or poor health increased when dwelling status (rent vs. other) and number of people in the household were included in the raked weights, and it increased by almost 3% with all 9 variables included in the raked weights. This pattern was similar for prevalence of current smokers, where the prevalence estimate increased by almost 2% with the addition of dwelling status and number of people in the household and a further 2% when all 9 variables were applied in the raked weights.

Table 4 shows the differences and percentage differences in the prevalence estimates between poststratification and fully raked weights on a range of selected health conditions, behavioral health risk factors, and socioeconomic conditions. More than half of the variables showed minimal differences in their prevalence when fully raked weights were applied compared with using the poststratification weight.

Table 5 shows the estimates from SAMSS using both poststratified and raked weights and the estimates from the face-to-face surveys. Little difference is seen in the estimates for current asthma (SAMSS and HOS) and sufficient daily consumption of vegetables (SAMSS and AHS). The raked-weight estimates for diabetes, arthritis, psychological distress, current smokers, and undertaking sufficient physical activity are similar to the estimates from HOS and AHS, in contrast to the

Table 5. Comparison of Prevalence Estimates From Poststratified and Raked Weights With Face-to-Face Surveys, Australia, 2011–2013

	South Australian Monitoring and Surveillance System, 2013		South Australia Health Omnibus Survey, 2013 ($n = \sim3{,}000$)[a]	Australian Health Survey, 2011–2012 (South Australia Results Only) ($n = 2{,}508$)[b]
	Poststratified Weights	Fully Raked Weights		
Fair or poor health (self-rated), %	15.4	18.1		14.7
Diabetes, %	7.7	8.4	8.5	
Osteoporosis, %	4.5	4.7	6.0	
Arthritis, %	20.6	23.0	22.0	
Current asthma, %[c]	12.0	12.9	12.7[d]	
Psychological distress (Kessler 10), %	8.8	11.3		11.4
Body mass index				
Overweight and obese, %	58.9	61.5	58.6	
Normal, %	38.6	36.3	39.5	
Missing data, %	6.1	6.1	9.4	
Current smokers, %	12.7	16.3	16.7[e]	16.6
Sufficient physical activity, %[f]	41.6	40.4	39.7	
Sufficient daily consumption of fruit, %[f]	44.2	42.4		46.1
Sufficient daily consumption of vegetables, %[f]	11.7	11.1		10.0

[a] From reference 58.
[b] From reference 59.
[c] Have you ever been told by a doctor that you have asthma? Do you still have asthma?
[d] 2011 Health Omnibus Survey estimates.
[e] 2012 Health Omnibus Survey estimates.
[f] Persons aged 18 years or more.

poststratification estimates. The poststratification weight estimates for self-reported fair or poor health, overweight and obesity, and sufficient daily consumption of fruit are closer to the estimates from HOS and AHS compared with the raked estimates.

DISCUSSION

This study highlights that using the statistical weighting formula, raked weights can improve health and behavioral risk factor estimates by incorporating a range of sociodemographic variables to overcome bias in telephone surveys. With declining response rates and inadequate sampling frames, specific groups of the community (e.g., people who rent) are often underrepresented in telephone surveys that can result in an under- or overestimation of the prevalence of health indicators. These findings imply that, for some health estimates, the limited sociodemographics incorporated in poststratification weighting methods (age groups, sex, and area of residence) are not sufficient to reduce bias in health estimates of the general population. By incorporating the 6 additional sociodemographic variables in the raked weighting formula into surveillance data, this study has demonstrated that the estimates are more in line with the more expensive national and state-based face-to-face surveys. The raked-weighting methodology has made it relatively easy to add many sociodemographic variables, which was not possible with the traditional poststratification weighting methods.

To our knowledge, this study is the first of its kind in the Australian context. It is unique in having a large sample, so that the conclusions are likely to be generalizable to the Australian population and are also applicable internationally, given that many of the issues regarding bias in telephone surveys are similar (16, 17). Most international studies of this kind are from the United States using BRFSS data (12, 60–64). Our study used sociodemographic variables in the raked weights similar to those of BRFSS (65) with but a few minor differences. Our study used country of birthplace instead of race because race is not commonly used or collected in Australian health surveys. Similar findings included the following: minimal prevalence differences in diabetes, cardiovascular diseases (heart attack, stroke), and current asthma (60–63) (<1% differences) and large differences in prevalence estimates (1%–3%) for overweight and obesity, fair or poor health, and physical activity. The difference between current smoking estimates in our study was 3.6%, which is less than the differences of 6%–7% reported in the BRFSS (12, 60–63).

Comparing the raked health estimates with 2 face-to-face surveys (both include mobile-only households that are excluded from telephone surveys and used poststratification weights) produced mostly similar but some mixed results. Similar estimates were found for arthritis, psychological distress, current smokers, diabetes, vegetable consumption, and sufficient levels of physical activity. The prevalence of sufficient servings of fruit suggests that using raked weights (42.4%) moved away from the AHS estimate (46.1%). The higher prevalence in the AHS compared with the SAMSS, even though the questions were the same, could be explained by the additional interviewer prompt in the AHS and the inclusion of tomatoes in the definition of fruit (66). Similarly, the

raked weighted estimates for overweight and obesity (61.5%) were different from poststratification weights (58.9%) compared with HOS (58.6%). A possible explanation could be the larger proportion missing data from HOS (9.4%) compared with SAMSS (6.1%). The raked weighted estimate for fair or poor health (18.1%) was higher than the AHS estimate (14.7%). This difference could be attributable to mode effect; that is, people tend to report more socially desirable responses on the basis of survey mode. It has been suggested that, for nonfactual questions such as self-rated health or quality-of-life type questions, the physical presence of an interviewer can cause the respondent to give a more positive rating of their health (67).

Although some of the estimates examined in this study did not change when raked weights were applied, there were large changes in the estimates occurring among health indictors that were strongly related to groups underrepresented in telephone surveys because of noncoverage (exclusion of mobile-only households) and nonresponse, such as people who rent and young people (Table 1). Previous studies have shown that health estimates, with higher prevalence among socioeconomically disadvantaged households or younger people, can be underestimated in telephone surveys because of nonresponse bias (noncoverage and lower response rates) (23, 30). This is shown in our study where substantial changes occurred in the health estimates for food insecurity, mental health conditions, fair or poor health, overweight and obesity, and not sufficiently active. These estimates changed considerably with the addition of dwelling status (rent vs. other) in the raked weights (Table 3). This suggests the raked weights better adjust these estimates by eliminating some of the bias due to nonresponse and sampling coverage problems. However, if the current trends of mobile-only households continue to increase (25), then other efficient sampling strategies for chronic disease and surveillance systems may need further investigation to include the sociodemographic groups that are underrepresented in telephone surveys. As it stands, the current suggested methodologies for use in Australia that include mobile-only households in the sample frame (24, 68) are not feasible or sustainable and are too costly for use in SAMSS and similar systems.

The study design is robust because of the large, representative, statewide samples used and the large range of health conditions and health-related risk factors assessed. The raked-weighting methodology reliant on data from the census, which is conducted every 5 years, can be seen as a limitation. However, further analysis revealed minimal changes between the 2006 Census and the 2011 Census. Another limitation is that some sociodemographic variables or categories, which were considered important, could not be included because of insufficient sample size, such as Aboriginal and/or Torres Strait Islander status. Other limitations occurred when the question or categories were not comparable between SAMSS and the census, such as never married, separated, or divorced, or when the proportion of missing data was too high, such as for household income. It should also be noted that use of the census as the benchmark could also be introducing additional biases because of respondent error, processing error, partial or nonresponse, and undercount since the census is a self-completed survey. About 3.7% of the census forms were not returned

from a private dwelling in 2011, and the count data were imputed on the basis of similar dwellings in the surrounding area. Variable item nonresponse for South Australia ranged from 0.9% to 14.2% with a median rate of 4.5%, and the variables that had high nonresponse were residential status in a nonprivate dwelling, that is, communal type of accommodations (14.2%) (not used in this study), and the highest year of school completed (7.5%) (used with other training and education variables). Given that around 5% of the census data items used in the raking methodology are imputed, we are confident that the estimates would be slightly biased.

The use of a raking weighting methodology has overcome, to some extent, the nonresponse bias associated with the sampling methodology of telephone surveys. Raking methodology has the advantage over poststratification methods for surveillance data from a relatively small sample size and the option to incorporate more sociodemographic variables. Our results suggest that raking methodology for telephone surveys requires additional sociodemographic variables besides the usual age, sex, and area that were previously used and that the estimates correspond well with those from face-to-face surveys. Surveillance systems are always evolving to accommodate technological and societal changes. Implementing raked weights in surveillance systems will change the prevalence of some estimates and will cause breaks in trend data. Therefore, strategies are needed to educated users on

the changes in methodology to avoid misinterpretation of the findings.

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APPENDIX

Raked Weight Adjustment Methods

The raking steps are as follows:

  Set weight = design weight.

  Repeat the following steps until reached tolerance level for all margins or the number of iterations = 60.

    For each v margin variable

      Calculate weighted sample total = sum(weight);

      Calculate weighted totals for each category in variable v = sum(weight$_{v \text{ categories}}$);

      Weight = weight × % population$_{v \text{ categories}}$ / [sum(weight$_{v \text{ categories}}$)/sum(weight)];

    End

    Trim weights;

    Rescale weight if weighted sample total is not equal to total unweighted sample size;

  End

By use of the following notations where n is the total sample size; N is the total population size (census); v denotes variable; u denotes category; k is the number of variables; j is the number of categories within variable v; T_v is the population proportion (control totals) calculated for each category, j, in variable, v; i is the individual in the sample, n; m is the number of iterations; and $w_i^{(m,v)}$ is the weighting variable for individual i at iteration m and variable, v, the raked weights are calculated as follows:

  Initialize;

    $T_v = N_{v,u}/N_v$, calculate the population control totals for each $v = 1, \ldots, k$ variables each with $u = 1, \ldots, j$ categories;

    $m = 0$, initialize iteration variable;

    $w_i^{(0,0)}$ = design weight, set the weight variable to the sample design weight

For iteration 1, $m = 1$, do the following for each v margin variable ($v = 1, \ldots, k$):

  Do the following for each u categories ($u = 1, \ldots, j$):

$$w_i^{(1,k)} = w_i^{(1,k-1)} \times T_k \times \left(\frac{\sum w_{i,k,u}^{(1,k-1)}}{\sum w_{i,k}^{(1,k-1)}} \right).$$

Reiterate the above calculations until the tolerance level has been reached for all k margins (i.e., $T_k - (\sum w_{i,k,u}^{(m,k)}/\sum w_{i,k}^{(m,k)}) < 0.025$; or the number of iterations, m, has been reached such as 60:

For iteration, m, do the following, where $v = 1, \ldots, k$

  Do the following for each u category ($u = 1, \ldots, j$):

$$w_i^{(m,k)} = w_i^{(m,k-1)} \times T_k \times \left(\frac{\sum w_{i,k,u}^{(m,k-1)}}{\sum w_{i,k}^{(m,k-1)}} \right).$$

Poststratification Weight Adjustment Methods

The traditional poststratification weighting (or cell weighting) applied for each individual (which includes the design weight in the formula), each month is

$$w_{h,i} = d_{h,i} \times \frac{N_h}{\sum_{i=1}^{n_h} d_{h,i}} \times \frac{n}{N},$$

where N is the total population size; n is the total sample size; h is the stratum, age groups $\times$ sex $\times$ area of residence; N_h is the population size of stratum h; n_h is the sample size in stratum h; $w_{h,i}$ is the weighting value for respondent i in stratum h; and $d_{h,i}$ is the household size for respondent i in stratum h.

Pre-Survey Text Messages (SMS) Improve Participation Rate in an Australian Mobile Telephone Survey: An Experimental Study

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Abstract

Mobile telephone numbers are increasingly being included in household surveys samples. As approach letters cannot be sent because many do not have address details, alternatives approaches have been considered. This study assesses the effectiveness of sending a short message service (SMS) to a random sample of mobile telephone numbers to increase response rates. A simple random sample of 9000 Australian mobile telephone numbers: 4500 were randomly assigned to be sent a pre-notification SMS, and the remaining 4500 did not have a SMS sent. Adults aged 18 years and over, and currently in paid employment, were eligible to participate. American Association for Public Opinion Research formulas were used to calculated response cooperation and refusal rates. Response and cooperation rate were higher for the SMS groups (12.4% and 28.6% respectively) than the group with no SMS (7.7% and 16.0%). Refusal rates were lower for the SMS group (27.3%) than the group with no SMS (35.9%). When asked, 85.8% of the pre-notification group indicated they remembered receiving a SMS about the study. Sending a pre-notification SMS is effective in improving participation in population-based surveys. Response rates were increased by 60% and cooperation rates by 79%.

1 Introduction

Many chronic disease and risk factor surveillance systems in Australia use the telephone as an efficient way to collect information. The telecommunication industry has undergone many changes over the last 15 years which has had an impact on traditional landline-based surveys. Increased non-coverage and declining participation has required telephone survey researchers to adjust their methodology.[1, 2] There has been an increase in mobile-only households in Australia and internationally,[3–5] and this has had an impact on the coverage of landline-based surveys.[2, 6] As a result many systems are incorporating mobile telephone samples into their surveys resulting in dual-frame sampling methods.[2, 7–9]

Abbreviations: AAPOR, American Association for Public Opinion Research; AWB, Australian Workplace Barometer; CON, contact rates; COOP, cooperation rates; MXT, web messaging platform; PAL, primary approach letter; RDD, random-digit dial; REF, refusal rates; RR, response rates; SMS, Short Message Service.

Incorporating mobile telephones samples into population surveys has brought challenges in both sampling and participation.[10, 11] In Australia, there is the difficulty in obtaining a representative sampling frame of mobile telephone numbers since they are rarely listed (7.3% of mobile telephone owners in South Australia are listed).[12] Several studies in Australia used a random-digit dial (RDD) list of mobile telephone numbers[13, 14] but this is compromised as mobile telephone numbers do not include address details or geographical location. As such, sending a primary approach letter (PAL) is not possible for geographically restricted surveys. Landline telephone numbers from directory-listed sampling frames that include address details allow the option of sending a PAL, which softens the impact of unsolicited calls and has been shown to improve response rates.[15]

There are a number of factors which have influenced people's participation in surveys using mobile telephones. The function of caller ID has contributed to this decline in response rates due to privacy concerns, survey burden and has enable the user to screen calls.[16] People are worried about the invasion of their privacy and have developed a mistrust of unsolicited calls.[17] A United States (US) study indicated that only 44% of people would let the call go to voice mail, 10% would ignore the call all together and 44% will answer the call.[18] The different 'user culture' associated with mobile telephones includes people regarding their mobiles as a private tool when compared to landline telephones with mobile telephones predominately used to converse with close friends and family members.[19] This makes it increasingly difficult to make 'cold' calls to mobile telephones.[20] Another challenge is the location at the time of data collection with landline interviews undertaken within the respondent's home while mobile interviews can additionally be undertaken in a wide range of environments outside the home. This means interviews via mobile telephones increases cognitive burden, therefore providing additional distractions, and challenges privacy considerations which can lead to higher break-off or refusal to participate.[21, 22] Unlike landline telephones, mobile telephones have various platforms: different operating systems, features, screen sizes, touch screens, keyboard or keypad options, different modes or formats of text messaging; all which have an impact on the way people interact or use their mobile telephones.[11] These issues are associated with lower response rates for mobile telephone interviews compared to landline telephone surveys resulting in the need for alternative methods to increase response rates.

A standard feature of mobile telephones is the ability to communicate by Short Message Service (SMS) or, more commonly known as, text messaging. In Australia, 85% of adults owning a mobile telephone indicated that they use SMS.[23] It is a relatively cheap way of communicating with a higher proportion of young people opting to SMS rather than call.[24] SMS has been used for many years in businesses as a reminder to clients of their appointment time and date.[25] This indicates the potential to incorporate SMS into survey methodology and improve response rates, especially among the difficult to reach groups such as the young and highly mobile people. Unlike PAL, SMS is considered fast, is received immediately or stored until the message is able to be read, and there is an immediate notification of a non-working number. With current available technology, SMS can be sent simultaneously to a large number of people.

Few studies have tested the effectiveness of sending pre-notification SMS to increase participation in population-based mobile telephone surveys. These previous studies indicated that there are no differences in the response rates for those who were sent a pre-notification SMS compared to those who were not.[20, 21, 26, 27] Although the response rate was not different, Steeh et al[20] found that surveys incorporating a pre-notification SMS had an increased cooperation rate (50.1% compared to 41.5%), lower refusal rate (10.3% compared to 21.1%) and fewer call attempts compared to no SMS. In a study conducted by DuBray,[26] only a third of the respondents indicated they recalled receiving a pre-notification SMS (33%) which could

explain the lack of observed difference in response rate. It should be noted that these studies were conducted in the US where the receiver of the incoming SMS pays for the incoming call. [19, 20] However, the payment system in Australia and Europe is different, with cost of the SMS paid by the person or organization sending the SMS.

The current study was designed to examine the role of SMS in increasing response rates in Australia. This study was part of a broader project which included current workers.[28] Previous data collection for the project was solely based on a directory-listed landline sampling frame. Literature indicated that the proportion of currently employed adults had higher rates of mobile-only households, and limiting the sample to a directory-listed landline sampling frame would result in a lower proportion of young people, people living in lower socio-economic status (SES) areas, and renters.[3, 5] Thus, a dual-frame telephone sampling approach was considered. This involved two different telephone sampling frames: a landline telephone sample and a mobile telephone sample.

The aim of this study was to test if sending pre-notification SMS to inform users of an imminent mobile telephone call from researchers about a survey improves response rates and participation in a population-based study among mobile telephone users. Because the uptake and saturation of mobile telephones has grown so quickly since the mid2000s[3, 5], and the technology has changed and evolved over the last decade as well as people's behaviours[29], the literature in this area is sparse and, moreover, findings from five years ago may not be relevant or applicable today.

2 Materials and Methods

2.1 Survey design and sample selection

This study is part of the Australian Workplace Barometer (AWB) project which aims to provide epidemiological evidence of Australian workplace conditions.[28] For this paper, only the methodology for the mobile telephone study will be presented. The sample frame used a randomly generated mobile telephone number supplied by Sampleworx.[12] Since the sample had no geographical marker, the sample could not be stratified by state or territory, hence, the mobile telephone sample was a random selection of mobile numbers of Australia.

Ethical approvals were obtained from the Research Ethics Committees of The University of Adelaide and the University of South Australia at each stage of the AWB project including this study to test sending a pre-notification text. Participation in the study is voluntary. Verbal informed consent was obtained from participants at the start of the interview and confirmation to continue participation in the telephone interview was obtained and recorded as yes or refusal within the questionnaire. The study was conducted via the mobile telephone and obtaining written consent or sending a primary approach letter (PAL) was not feasible due to inability and unwillingness of respondents to provide mailing address details. Upon initial contact, respondents can have a PAL mailed out if requested. Consent was recorded as a complete interview and reasons for non-participation or unable to establish contact were also recorded.

A simple random sample of 9000 mobile telephone numbers Australia-wide was selected. To determine the effectiveness of sending a pre-notification SMS, 4500 mobile numbers were randomly selected to be sent a SMS. To be eligible for participation, respondents had to be an adult aged 18 years and over, and currently in paid employment. We assumed that the person who answered the mobile telephone was the primary user. People who were self-employed were not eligible to participate. There were no replacements for non-contactable persons. Data collection for this study occurred between 29 October 2014 and 23 February 2015. All interviews were conducted in English.

2.2 SMS messages

SMS messages were sent using smsglobal (www.smsglobal.com), a web messaging platform (MXT), which is a management tool to send SMS online. The MXT has options to send from a dedicated number or from words limited to 11 characters. We chose to have "Uni SA AWB" since the University of South Australia is a well-known and respected institution, and the results from an internet search using these terms provides links to AWB material. The length of the message was set at the standard 160 characters (including spaces). The 160 characters was costed as one SMS message; any more would have doubled the cost. The main aim of the message was to inform the participant that they were going to receive a call, the number that was going to be used and a free-call 1800 number to call if they had any queries. The respondents did not have the option to reply by sending a SMS. Random batches of mobile numbers were selected daily and scheduled for SMS to be sent at noon each day with the telephone call made later that evening. Smsglobal software flags SMS messages that were unsuccessfully sent, indicating that the mobile telephone number was not active and could be removed from the sample. As part of the market and social research industry standards in Australia, both sample groups had the telephone number of the caller appearing on the screen, in this case, a landline telephone number. No other information, such as "UNI SA AWB" appeared when calling to the mobile telephone. Up to three SMS were sent to the participants to obtain an interview. The follow-up SMS messages were worded almost the same as the initial SMS (see Appendix 1). For both sample groups, if there was no answer, the interviewer left a voice message if possible (see Appendix 2). Up to five call-backs were made to establish contact.

2.3 Socio-demographics

Socio-demographic variables included in these analyses were age group, sex, country of birth (Australia, outside Australia), educational attainment (bachelor degree level or higher, below bachelor level), and working hours (full time, part time).

2.4 Statistical analyses

The response rate was used to determine the effectiveness of pre-notification SMS. The final dispositions of the mobile telephone numbers were classified using the American Association for Public Opinion Research (AAPOR) standard definitions.[30] A series of outcome rates[30] were calculated to evaluate the performance between the SMS and no SMS mobile telephone groups. There are different formulas for each rate to incorporate the unknown eligibilities of some mobile telephones:

- response rates (RR): The number of complete interviews divided by the number of eligible respondents in the sample.

- cooperation rates (COOP): The number of all cases interviewed divided by all eligible respondents ever contacted.

- refusal rates (REF): The number of all respondents who refused to be interviewed, or terminated an interview, divided by all potentially eligible cases.

- contact rates (CON): The proportion of all cases in which some responsible housing unit member was reached.

Univariable analyses using chi-square tests were conducted to compare each of the outcomes rates and socio-demographic characteristics between the SMS and no SMS mobile telephone groups. In addition, to examine the representativeness of the two mobile telephone

groups with regard to selected socio-demographic characteristics (prevalence (%) and 95% confidence intervals), comparisons were made against the Australian Bureau of Statistics (ABS) Census [31] data of people in paid employment (excluding self-employed).

Data analysis was conducted using SPSS Version 21.0.

3 Results

From the original sample of 9000 mobile telephone numbers, 3809 were ineligible due to being a non-connected number (1755), non-residential number (102), fax/modem connection (23), pager service (191) and the respondent being ineligible to participate in the survey (1738) (Table 1). Ineligible respondents were mainly due to being aged under 18 years (530) and either self-employed or not employed (1208). This left an eligible sample of 5191 mobile telephone numbers: 2566 that were sent a pre-notification SMS and 2625 that were not sent a pre-notification SMS.

A total of 526 eligible adults participated in the survey; 60.4% were sent a pre-notification SMS (318) and 39.5% were not (208). The response rate was 12.4% (RR1) for the mobile sample that was sent a pre-notification SMS and 7.7% for the sample that was not (Table 1). The SMS mobile telephone group had a higher cooperation rate (COOP1, 28.6% versus 16.0%) and a lower refusal rate (REF1, 27.3% versus 35.9%) compared to the mobile telephone group with no SMS.

The average time of the two surveys did not differ: 32.8 minutes (standard deviation = 7.62) for respondents who received a SMS and 33.2 minutes (standard deviation = 7.62) for those who did not.

Even though the toll-free 1800 number was given in the SMS, only seven people rang to opt-out of the survey. Statistics on the number of people using the 1800 number to query the survey were not recorded. When asked, 85.8% of the pre-notification SMS group remembered receiving a SMS about the study. There were no differences between males and females in the proportion of recall, however, recall was lower amongst respondents aged 18 to 24 years (80.5%) and 55 and years and over (81.4%).

When examined against the ABS Census population (Table 2), there were no differences in the two mobile telephone groups by sex. There was no clear pattern by age groups for either mobile telephone group, with some age groups close to the Census population. Even though the two mobile telephone sample groups did not differ to each other in terms of educational level and country of birth, both groups had a higher proportion of respondents with a bachelor degree or higher level of education and respondents born outside of Australia compared to the Census population. The SMS mobile telephone group had the same employment hours distribution as the Census whereas the no SMS group had a lower proportion of fulltime participants.

4 Discussion

The results of our study showed that sending a pre-notification SMS was effective in improving participation in population-based surveys using a RDD list of mobile telephones as the sampling frame. Although the absolute response rate was low, this feature increased the response rates (RR1) by 60%, cooperation rate (COOP1) by 79% and lowered refusal rates (REF1) by 24%. Our study contradicts other results in the literature, with our study indicating an improvement in response rates in the SMS mobile telephone group.[20, 21, 26, 27] A possible reason for this could be that this study was conducted in Australia and there could be different legal or legislation issues, and cultural differences in familiarity and ability in using SMS features in mobile telephones. In addition, the different payment system in Australia, whereby the

Table 1. AWB Response rates: mobile telephone sample [using American Association for Public Opinion Research standards][30].

	No pre-notification SMS	Pre-notification SMS	P value
Interview (Category 1)			
Complete	203	317	
Eligible, non-interview (Category 2)			
Refusal and breakoff (terminated)	15	15	
Refusal	928	685	
Non-contact			
Respondent never available	1	2	
Answering machine household-message left	27	9	
Other, non-refusals			
Physically or mentally unable/incompetent	10	9	
Language problem	113	84	
Unknown eligibility, non-interview (Category 3)			
Always busy	2	0	
No answer	1326	1445	
Not eligible (Category 4)			
Fax/data line	9	14	
Disconnected number	891	864	
Special technological circumstances			
Pager	95	96	
Non-residential number	60	42	
No eligible respondent	820	918	
Total phone numbers used	4500	4500	
I = Complete Interviews (1.1)	203	317	
P = Partial Interviews (1.2)	0	0	
R = Refusal and break off (2.1)	943	700	
NC = Non Contact (2.2)	28	11	
O = Other (2.0, 2.3)	123	93	
Calculating e:	0.41	0.37	
UH = Unknown Household (3.1)	1328	1445	
UO = Unknown other (3.2–3.9)	0	0	
Response Rate 1 [& 2] I/(I+P) + (R+NC+O) + (UH+UO)	7.7	12.4	<0.001
Response Rate 3 [& 4] I/((I+P) + (R+NC+O) + e(UH+UO))	11.0	19.2	<0.001
Cooperation Rate 1 [& 2] I/(I+P)+R+O	16.0	28.6	<0.001
Cooperation Rate 3 [& 4] I/((I+P)+R))	17.7	31.2	<0.001
Refusal Rate 1 R/((I+P)+(R+NC+O) + UH + UO))	35.9	27.3	<0.001
Refusal Rate 2 R/((I+P)+(R+NC+O) + e(UH + UO))	51.2	42.4	<0.001
Refusal Rate 3 R/((I+P)+(R+NC+O))	72.7	62.4	<0.001
Contact Rate 1 (I+P)+R+O / (I+P)+R+O+NC+ (UH + UO)	48.3	43.3	<0.001
Contact Rate 2 (I+P)+R+O / (I+P)+R+O+NC + e(UH+UO)	69.0	67.2	0.27
Contact Rate 3 (I+P)+R+O / (I+P)+R+O+NC	97.8	99.0	0.02

e is the estimated proportion of cases of unknown eligibility that are eligible.[30] Enter a different value or accept the estimate in this line as a default. This estimate is based on the proportion of eligible units among all units in the sample for which a definitive determination of status was obtained (a conservative estimate).

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researcher pays for both SMS and call to the participant, could make this methodology more acceptable. In comparison, for example, in the US, the receiver of the SMS or call to the mobile

Table 2. Demographic profile by pre-notification SMS mobile telephone groups.

	ABS Censusemployed	No pre-notification SMS		Pre-notification SMS		
	%	n	%	n	%	P value
Sex						
Male	50.1	104	51.2 (44.4–58.0)	160	50.5 (45.0–55.9)	0.87
Female	49.9	99	48.8 (42.0–55.6)	157	49.5 (44.1–55.0)	
Age groups						
18–24 years	15.2	32	15.9 (11.5–21.6)	41	12.9 (9.7–17.1)	0.22
25–34 years	24.4	41	20.4 (15.4–26.5)	81	25.6 (21.1–30.6)	
35–44 years	23.3	47	23.4 (18.1–29.7)	57	18.0 (14.1–22.6)	
45–54 years	21.9	53	26.4 (20.8–32.9)	79	24.9 (20.5–30.0)	
55–64 years	13.1	19	9.5 (6.1–14.3)	47	14.8 (11.3–19.2)	
65+	2.1	9	4.5 (2.4–8.3)	12	3.8 (2.2–6.5)	
Education level						
Bachelor degree or higher	23.8	83	40.9 (34.4–47.8)	115	36.3 (31.2–41.7)	0.29
Below bachelor level	76.2	120	59.1 (52.2–65.6)	202	63.7 (58.3–68.8)	
Country of birth						
Australia	72.4	132	65.3 (58.6–71.6)	218	68.8 (63.5–73.6)	0.42
Outside Australia	27.6	70	34.7 (28.4–41.4)	99	31.2 (26.4–36.5)	
Working hours						
Full time	70.4	120	60.9 (54.0–67.5)	220	70.7 (65.5–75.5)	0.02
Part time	29.6	77	39.1 (32.5–46.0)	91	29.3 (24.5–34.5)	

ABS: Australian Bureau of Statistics [31]

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telephone incurs the cost, not the sender or person making the call.[32] Therefore, the participants in our study were not refusing to participate because of cost. Three of these previous studies[20, 21, 27] were conducted over eight years ago (2004 to 2007) where the SMS features were most likely not as widely used or familiar, or a standard feature of the device. Also our participants were more likely to recall receiving the SMS (85.8%) compared to a recent study by DuBray (33%) which could explain why they found no differences in the response rates.[26] Although, Steeh et al[20] found no differences in the response rates, our findings were similar to theirs in terms of increased cooperation rates and decreased refusal rates.

This study is unique as it is the first of its kind in Australia, and its strength lies in its population approach using a large Australia-wide sample rather than a convenient sample. It is also timely and has been undertaken in a population which is more accepting of SMS in terms of usage and familiarity; in 2011, 78% of Australians who owned a mobile telephone regularly used SMS and this increased to 85% in 2014.[23] However, there are weaknesses associated with this study. Since our SMS was sent in English only and our study was limited to people who were currently employed, the majority were aged between 18 and 64 years, and therefore we cannot infer that the results are generalizable to the whole population. Up to 3% of Australians, 10 years and over, do not speak English well or not at all (2.5% do not speak English well or and 0.5% do not speak English at all (0.5%) [31], and an Australian study found that 3.7% of people aged 15 to 74 years had poor literacy skills (below Level 1) [33]. As Australia's population is linguistically diverse, with 400 languages spoken, including Indigenous languages, it is not possible to send SMS in different languages. It is not known for Australian migrants who do not understand English how they overcome these issues, but some migrants have use free online translation softwares, such as Google Tranlate®, or dictionary apps, such as Bing

Translator® to overcome the language barrier. Given this, we can assume there still will be up to 3.7% of the population with poor literacy skills that would not understand our SMS message and mostly likely not participate in general population surveys.

There are other limitations in regards to the application of using SMS for surveys. These include the additional cost in sending a SMS (0.10c per SMS) and administration, although this cost was lower than sending a PAL (paper, printing, postage and envelopes). To limit recall bias, the SMS was sent during the morning of the planned telephone call. As a result, this created additional daily workload for administration staff. Feedback from the administration staff found the process relatively easy using appropriate software. Also, to minimize cost, the length of the message was limited to 160 maximum characters; any more would have doubled the cost per SMS (0.20c per SMS with maximum of 320 characters). This means, unlike the tradition PAL, our SMS did not include more detail about who was conducting the study, justify the nature of the study, the role of the respondent, the importance of the respondent's participation, and assurances of anonymity and confidentiality. The SMS method had an added benefit in providing the status of the mobile telephone number immediately after sending the SMS so that disconnected numbers could be removed from the sample saving costs in terms of interviewer time.

The concept of the pre-notification SMS is to eliminate the element of surprise or misunderstanding and to indicate that the call is legitimate. The SMS was also designed to overcome the problem of an unrecognized telephone number on the caller-ID that may be ignored. This is important in today's culture of increasing mistrust of unsolicited calls and provides the respondent the option to investigate the legitimacy of the incoming number if they wish. Unlike landline telephones, mobile telephones are usually attached to a person and not a household. Our study had a very small number of people using the toll-free 1800 number to opt out which might suggest that people did not feel suspicious about our study. General feedback from the interviewers found that pre-notification SMS made a minor impact on the respondents being more receptive or interested in the survey. We did not provide the option for the respondents to reply by sending a SMS as this was seen as an easy way to opt-out and also to avoid nuisance or abusive SMSs.

It should be noted that this is a relatively new surveying area and the general population may not be familiar with receiving research market calls as they do on landlines. Furthermore, unlike other methods such as landline or online internet, mobile telephones have not yet been extensively overused by marketing companies and spammers. Continual monitoring of response rates for population surveys using a mobile telephone sample is required to see if the benefit is upheld. Using SMS is one feature of mobile telephones we can utilize. Mobile telephones are continually evolving with smartphones being the next generation that researchers can explore possibilities of incorporating other types of pre-notification messages such as links embedded to webpage with additional details of the study, voice messages in which the respondent can choose their language, and the use of multimedia message.

5 Conclusion

This study has shown the benefits of sending a pre-notification SMS with improvements in response and cooperation rates, and reduction in refusal rates, for population surveys using mobile telephones. Further research is needed to apply this method to incorporate the total population to determine if the results found in this study are generalizable to the whole of the population. In addition, given that mobile telephone technology is continually changing and the general population's behaviours are also changing with it, these studies need to be conducted regularly.

Appendix 1

SMS received from "Uni SA AWB".

Initial SMS:

You have been chosen to participate in an important Australian Research Council survey. An interviewer will ring on 9999 9999. RSCHD 1800999999. Thank you.

Follow-up SMS:

You have been chosen to participate in an important Australian Research Council survey. An interviewer will ring on 9999 9999. RSCHD 1800999999. Thank you.

Appendix 2

Hi, my name is . . .. Calling on behalf of the University of South Australia. Sorry we missed you but we will try calling again at a later date.

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Author Contributions

Conceived and designed the experiments: EDG AWT MD. Performed the experiments: EDG AWT MD. Analyzed the data: EDG. Contributed reagents/materials/analysis tools: EDG AWT CRC SC. Wrote the paper: EDG AWT CRC SC MD.

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