The Australian Diabetes Obesity and Lifestyle Study (AusDiab)

Five year follow-up

Results for New South Wales

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Table of contents

Tables

Figures

Executive summary

Diabetes and cardiovascular disease contribute significantly to Australia's burden of illness and death, with these conditions together accounting for over 30% of all deaths in Australia (1). However, as there are no nationally representative longitudinal data on diabetes, it is very difficult to determine the incidence of this condition within the Australian population. Understanding the natural history of diabetes will help to determine the extent to which hypertension, dyslipidemia, obesity and various levels of glucose intolerance, such as impaired glucose tolerance (IGT) and impaired fasting glucose (IFG) contribute to the future development of type 2 diabetes in the Australian setting.

The Australian Diabetes, Obesity and Lifestyle (AusDiab) is the first Australian longitudinal population-based study established to examine the natural history of diabetes and its complications, as well as heart disease and kidney disease. This important health initiative forms an integral component of the National Diabetes Strategy to tackle the mounting problem of diabetes in Australia. The baseline study, conducted in 1999-2000 was commissioned and funded by the Commonwealth Department of Health and Ageing, with support from a number of non-government associations, pharmaceutical and diagnostic companies, and several state governments including that of New South Wales (NSW). The five-year follow-up study addresses the important gaps that exist nationally and internationally in the understanding of the burden of diabetes and related problems.

This report presents the key findings relating to participants in NSW. The follow-up study is still continuing and a full report for the total AusDiab study will be provided in 2006.

Summary of results for New South Wales

- Of the 1478 participants from the baseline study who were eligible for follow-up testing in NSW, 895 (60.6%) individuals attended the AusDiab follow-up survey in 2004.

- The overall incidence of diabetes was 8/1,000 population/year. The majority of new diabetes cases in 2004 were previously classified as having either IGT or IFG at baseline.

- The incidence of IFG was 9/1,000 population/year. The incidence of IGT was 15/1,000 population/year.

- There was a mean weight gain of 1.1 kg over five years, with 18.1% of individuals not previously obese progressing to a higher weight category. For those who were obese in 1999 only 7.8% moved to a lower weight category after five years.

- The mean values for total cholesterol (TC) and low-density lipoprotein cholesterol (LDL) significantly improved over the five years with mean reductions of 0.35 mmol/L and 0.31 mmol/L respectively. There was a small mean reduction of 0.03mmol/L of high-density lipoprotein cholesterol (HDL), whereas triglyceride levels remained unchanged.

- The prevalence of self-reported lipid-lowering medication use increased from 8.4% in 1999 to 13.7% in 2004.

- Between 1999 and 2004, there was a mean decrease of 9.1 mmHg in systolic blood pressure and a mean decrease of 4.0 mmHg for diastolic blood pressure.

- Antihypertensive use increased from 14.2% in 1999 to 16.9% in 2004.

Conclusions

The incidence of diabetes at 8/1,000/year was similar to other studies. The incidence of IFG was 9/1,000/year and the incidence of IGT was 15/1,000/year. On average, people gained 1.1 kg over five years. More people reported taking both lipid-lowering and antihypertensive medication in 2004 compared with 1999. Change in medication use may be one factor that explains the improvement in TC, LDL and blood pressure profiles.

1. Background

Diabetes and cardiovascular disease contribute significantly to Australia's burden of illness and death, with these conditions together accounting for over 30% of all deaths in Australia (1). However, as there are no nationally representative longitudinal data on diabetes, it is very difficult to determine the incidence of these conditions within the Australian population. Understanding the natural history of diabetes will help to determine the extent to which hypertension, dyslipidemia, obesity and various levels of glucose intolerance, such as impaired glucose tolerance (IGT) and impaired fasting glucose (IFG) contribute to the future development of type 2 diabetes in the Australian setting. The importance of longitudinal data cannot be overstated, as it also provides vital information for both public health planning and for advising and treating those individuals at personal risk of diabetes, renal and cardiovascular disease.

The Australian Diabetes, Obesity and Lifestyle (AusDiab) is the first national Australian longitudinal population-based study established to examine the natural history of diabetes and its complications, as well as heart disease and kidney disease. This important health initiative forms an integral component of the National Diabetes Strategy to tackle the mounting problem of diabetes in Australia. The baseline study was commissioned and funded by the Commonwealth Department of Health and Ageing, with support from a number of pharmaceutical and diagnostic companies, and several state governments including that of New South Wales (NSW). The AusDiab follow-up study addresses the important gaps that exist nationally and internationally in the understanding of the burden of diabetes and related problems.

The baseline component of the AusDiab study was a cross-sectional population-based study conducted during 1999-2000, which consisted of a nationally representative sample of 11,247 adults who underwent glucose tolerance testing, measurement of cardiovascular risk factors, and assessment of lifestyle parameters (2). AusDiab revealed a diabetes prevalence of 7.4%, one of the highest for a western nation, and indicated that the number of people with diabetes in Australia had more than doubled since 1981 (3). The five-year follow-up study involves inviting AusDiab participants to return for another biomedical assessment, which will include an oral glucose tolerance test (OGTT). The overall aims of the AusDiab follow-up are:

- to determine Australia's health burden from type 2 diabetes;
- to describe the natural history of type 2 diabetes, and other states of glucose intolerance, and associated cardiovascular disease risk markers and complications;
- to identify risk markers associated with worsening glucose tolerance status and the development of diabetic complications including cardiovascular disease;
- to develop models for prediction of cardiovascular disease in the Australian diabetic and non-diabetic populations;
- to compare outcomes between those previously diagnosed with diabetes and those newly diagnosed in the AusDiab study;
- to measure the progression of renal disease in both the diabetic and non-diabetic population;
- to determine the relative importance of diet and exercise in the development of obesity and diabetes;

- to determine an efficient screening strategy for undiagnosed type 2 diabetes;
- to quantify the risks associated with the metabolic syndrome in the Australian population.

This report presents the key findings relating to participants residing in NSW. The five-year follow-up study is still continuing and a full report for the total AusDiab study will be provided in 2006.

2. Methods

The follow-up AusDiab study involved inviting all participants from the baseline study to another survey and physical examination during 2004-2005. The survey closely replicates the baseline AusDiab survey, and involved a team travelling around Australia to test participants for diabetes, heart and kidney disease.

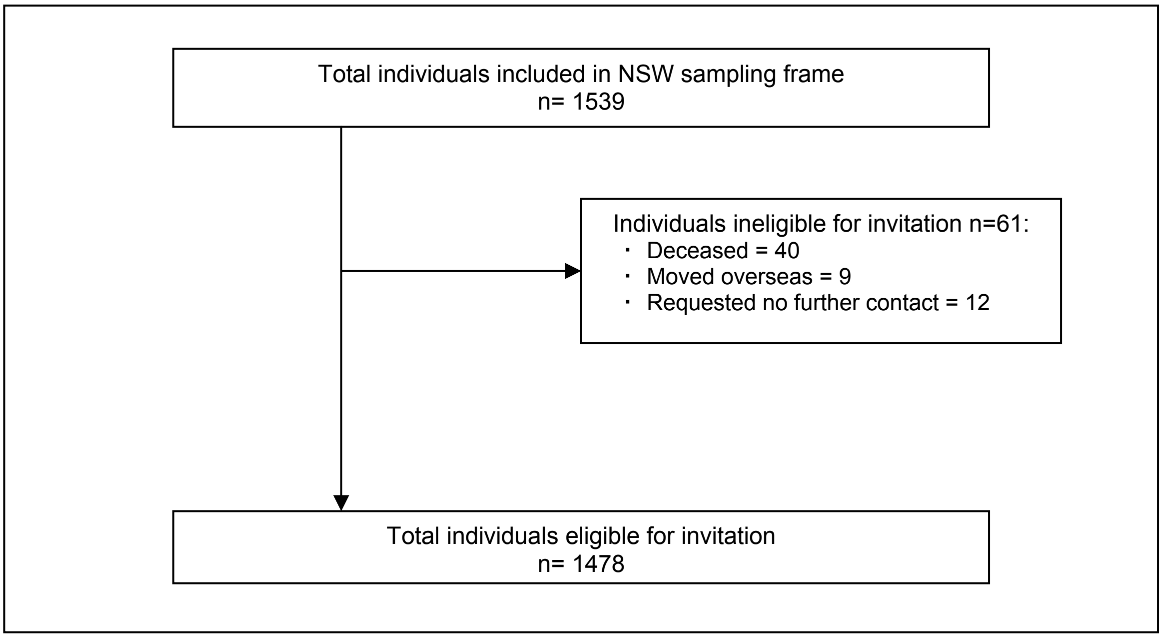
2.1 Sample selection and eligibility

The baseline AusDiab (1999-2000) study was a population-based national survey of the Australian general population aged ≥25 years residing in 42 randomly selected urban and rural areas (census collector districts) in six states and the Northern Territory. Full details of the sampling frame, methods and response rates for AusDiab have been previously published (2) (Appendix D). The testing sites in NSW were Grays Point, Hurstville, Orange, Berkeley Vale, West Pennant Hills and Auburn. As a number of participants moved to the Australian Capital Territory (ACT) since 1999 – 2000, testing was also conducted in Canberra. (Appendix A).

Over the five years since the completion of the baseline study, some participants have moved from their original testing site. These individuals have been assigned a new testing site, which is located, where possible, in close proximity to their home. The total sampling frame for the follow-up AusDiab study in NSW therefore included any participant assigned to one of the NSW or ACT testing sites (Appendix A), including; (i) AusDiab participants originally tested in NSW, and not known to have left the state, and (ii) AusDiab participants who have moved to NSW or the ACT from other states. The total number of individuals included in the 2004 sampling frame is 1539 (see Figure 1). Therefore, as a result of these movements, this number differs from the number of individuals who participated in NSW in 1999 (n=1515). Participants who were tested in NSW in 1999 but who moved interstate will not be included in this NSW follow-up analysis. They will, however, be included in the national AusDiab follow-up.

Individuals considered ineligible for invitation to the follow-up study include: (i) participants known to be deceased; (ii) participants who have moved to another country, and (iii) participants who have requested not to be contacted (including participants who have moved into a nursing facility classified for high-care). Figure 1 summarises the number of individuals eligible for invitation to the follow-up study in NSW.

Figure 1. Sampling frame for the AusDiab follow-up in NSW.



2.2 Survey protocol and procedures

Participants are tested at each of the local allocated sites. A small number of individuals who could not attend were provided with the option to give blood at a local pathology laboratory. Testing commenced in June 2004 and the entire five-year follow-up is expected to take 17 months, with completion in November 2005. Testing takes place in the same order as originally conducted for the baseline study, thus ensuring that most participants will have the same follow-up period between 1999 and 2005. In NSW, testing started on October 26th and finished on December 15th 2004 (Appendix A).

2.2.1 Preparation of survey methods and training

The preparation of the survey methods, including both the physical examination equipment and questionnaires, was undertaken in accordance with the study objectives as outlined above, with a specific emphasis on having a direct comparability with the methods utilised in the baseline study.

A team of survey staff was recruited to administer the survey in each state. All staff attended a two-day training workshop, which was conducted by the study coordinators prior to collecting data. Staff were briefed on the survey's background, objectives and methodology to ensure accurate and consistent data collection.

2.2.2 Invitation and recruitment

To maintain current contact details and ensure maximum participation, contact with the AusDiab participants has been maintained since the baseline study by utilising annual telephone and postal contact, the Australian Electoral Roll database, online telephone directories, the Telstra White Pages directory on compact disk and information provided by the next-of-kin.

Invitation to the five-year follow-up involved:

- letters of invitation, sent six and four weeks prior to testing for each site;
- follow-up telephone calls for those who did not reply to the initial letters;

- follow-up telephone calls for all individuals who declined the invitation in order to request a reason for non-attendance and/or to re-schedule another appointment time if possible;
- reminder telephone calls two to three days prior to appointments for all individuals who had confirmed an appointment;
- telephone calls to all participants who did not attend their appointment, with the aim of re-scheduling another appointment.

2.3 Physical examination

The AusDiab physical examination procedures closely follow the study protocol as recommended by the World Health Organization for the study of diabetes and other non-communicable diseases (4). The physical examination was conducted on both weekdays and weekends over a four to seven day period in each of the sampled areas. Local survey sites included community halls, scout halls, sporting halls, church halls and schools. Survey activities at the testing site commenced at 7am and typically finished at 2pm. On average approximately 30 participants attended daily in NSW.

All participants gave written informed consent to participate in the survey upon arrival at the testing site. Personal information was verified on-site and entered into a computer database, and each individual was given a barcode based on their original AusDiab unique identification number. Participants were moved through the physical examination procedures in a circuit-like manner that took approximately 2.5 – 3 hours to complete. Participants were asked to remain on site until all tests were performed. Central to the physical examination was the standard two-hour OGTT, during which time all other procedures were performed.

2.3.1 Blood sampling, oral glucose tolerance test and laboratory procedures

Blood was collected by venepuncture after an overnight fast (≥9 hours). Serum triglycerides, total cholesterol (TC), and high density lipoprotein cholesterol (HDL) were measured by enzymatic methods. In 1999 an Olympus AU600 analyser (Olympus Optical Co. Ltd, Tokyo, Japan) was utilised, and in 2004 the Roche Modular (Roche Diagnostics, Indianapolis, USA), was used. Low-density lipoprotein cholesterol (LDL) was derived by calculation using the Friedewald formula (5). A 75g OGTT was performed on all participants, except those on insulin or oral hypoglycaemic drugs and those who were pregnant. In 1999 fasting and two-hour post-load plasma glucose levels were determined by a glucose oxidase method using an Olympus AU600 automated analyser (Olympus Optical Co. Ltd, Tokyo, Japan), and in 2004 a spectrophotometric-hexokinase method utilising a Roche Modular (Roche Diagnostics, Indianapolis, USA) was used. Blood specimens were centrifuged on-site and aliquoted for testing and storage. All samples were immediately stored on-site in a freezer at -20°C and then transferred to a -70°C storage facility within one to two weeks following collection. All analyses were conducted at a central laboratory (HITECH Pathology, Clayton, Victoria in 1999 and Gribbles Pathology, Clayton, Victoria in 2004). Laboratory analysis methods were comparable across both the 1999 and 2004 surveys (see Appendix C).

2.3.2 Classification of diabetes and impaired glucose metabolism

The diagnostic criteria for the presence of diabetes, IGT and IFG were based on values from the OGTT venous plasma glucose concentration as outlined by the World Health Organization (Table 1) (6). Participants were classified as having diabetes if they: (i) had either a fasting plasma glucose ≥7.0 mmol/l, or two-hour plasma glucose level ≥11.1 mmol/l; or (ii) reported receiving oral hypoglycaemic agents and/or insulin injections; or (ii) reported a history of physician-diagnosed diabetes controlled with diet therapy, and had blood glucose levels within the diabetes range (6). Women who reported having physician-diagnosed diabetes only during the term of their pregnancy were classified as having had gestational diabetes, and were classified as currently having normal glucose tolerance provided that their blood glucose levels were within the normal range.

Table 1. Values for the diagnoses of diabetes and other categories of hyperglycaemia according to the 1999 World Health Organization criteria.

Glucose tolerance status	Fasting plasma glucose		Two-hour post load plasma glucose
Diabetes	≥7.0 mmol/L	or	≥11.1 mmol/L
IGT	<7.0 mmol/L	and	7.8 – 11.0 mmol/L
IFG	6.1 – 6.9	and	<7.8 mmol/L

2.3.3 Anthropometry

Height was measured to the nearest 0.5 cm without shoes using a stadiometer. Weight was measured without shoes and excess clothing to the nearest 0.1 kg using a mechanical beam balance in 1999 and digital weighing scales in 2004. Body mass index (BMI) (kg/m^2) was calculated.

2.3.4 Blood pressure

Blood pressure measurements were performed in a seated position after rest for ≥5 minutes using an automated blood pressure monitor (Dinamap® Pro-series Monitor Model DP 101–NIBP, Pulse and recorder, GE Medical Systems Information Technologies, Milwaukee, USA). A cuff of suitable size was applied on the participant's exposed upper arm (the arm not used for blood collection), which was supported on a table at heart level. Three sequential measurements were taken, with a 30 second interval between them. All measurements were documented on the participant's form. The mean of the first two measurements were taken, however if the difference between the first and second measurement was greater than 10 mmHg, the third measurement was used, and the mean of the two closest readings was used.

2.3.5 Questionnaires

Interviewer-administered questionnaires were used to ascertain age, previous diagnosis of diabetes, exercise and medication use.

2.3.6 Data entry

Data from the questionnaires, height, weight and blood pressure were entered onto forms that could be scanned at the completion of testing, using the Teleform Information Capture Software (Cardiff Software Inc., Vista, CA). A data query system (AusDiab Data Query System, A Meehan, Department of Epidemiology, Monash University), which was specifically developed for the AusDiab study, was used to check for errors and missing data when the forms were scanned. Scanning occurred as each participant completed testing, so that inconsistencies could be rectified before the participant left the survey site.

2.4 Feedback to participants

All participants received a letter outlining some of their survey results. Participants were given the opportunity to request that their results also be sent to their general practitioner. Participants were sent letters approximately six to eight weeks following the completion of testing. People were encouraged to seek advice and follow-up where required from their doctor.

2.5 Statistical analysis

All analyses are based upon the 895 participants who attended both the 1999 and 2004 surveys. The 1999 prevalence rates for all individuals who participated in NSW in 1999 (n=1515) are also included for completeness. Differences in the baseline characteristics between attendees and non-attendees of the five-year follow-up survey were explored with an independent *t*-test, Mann-Whitney U test or Pearson's chi-square test where appropriate. Crude prevalence rates (%) for diabetes, obesity, abnormal lipid levels, hypertension, lipid-lowering and antihypertensive medication use were reported for 1999 and 2004. Age-standardised prevalence (%) was calculated by applying the 1999 NSW population distribution (7) to both the 1999 and 2004 AusDiab rates using the direct method. Annual incidence rates for each of the glucose intolerance categories were calculated from the five year incidence rates by applying the following formula: $(-\ln(1-S))/t$; where S is the proportion of new cases over t years and t equals the time of follow-up. Comparison of baseline characteristics between the incident diabetes cases and non-incident diabetes cases were tested with an independent *t*-test, Mann-Whitney U test or Pearson's chi-square test where appropriate. BMI measurements were categorised into three groups: (i) normal <25 kg/m^2; (ii) overweight ≥25 - <30 kg/m^2; and (iii) obese ≥30 kg/m^2. Hypertension was defined as the proportion of participants having a blood pressure ≥140/90 mmHg or reporting antihypertensive medication use. The classification of hypertension ≥140/90 mmHg was based upon the World Health Organization Guidelines (8). The percentage of participants failing to achieve TC <5.5 mmol/L, LDL <3.5 mmol/L, HDL >1.0 mmol/L or triglycerides <2.0 mmol/L were also determined. The cut-points for lipids were based on recommendations by the Heart Foundation (9, 10). The mean (or median) difference for weight (kg), systolic and diastolic blood pressure, TC, LDL, HDL and triglycerides between 1999 and 2004 was calculated. Paired *t*-tests were used to determine whether differences were significant. The age-adjusted mean difference for each of these variables between 1999 and 2004 was also calculated using cross-sectional time-series regression model (GLS random-effects model). The distributions of the continuous variables were checked for normality, and where appropriate, log transformations were conducted prior to analysis. Analyses were conducted with SPSS version 11.5 (SPSS, Chicago, IL, USA) and Stata Statistical Software vs 8.2 (StataCorp, College Station, Texas, USA).

2.6 Abbreviations

Abbreviations used in this report are listed in Appendix B.

3. Findings

3.1 Response rates

Of the 1478 individuals eligible for testing in NSW, 886 (59.9%) individuals attended the AusDiab follow-up survey in 2004 at one of the seven testing sites (including Canberra). Table 2 summarises the response rates for each of the NSW testing sites.

Table 2. Response rates according to NSW testing site.

Site	Number tested	Total Eligible	Response Rate (%)
Canberra	15	19	78.9
Grays Point	178	240	74.2
West Pennant Hills	203	311	65.3
Berkeley Vale	179	308	58.1
Orange	163	290	56.2
Hurstville	98	193	50.8
Auburn	50	117	42.7
Total	886	1478	59.9

Of the 1478 eligible individuals, 592 did not attend. Table 3 outlines the reasons provided by the people who did not attend.

Table 3. Reasons for non-attendance in NSW.

Reason for non-attendance	n	Percent
No reason recorded	136	23.0
No current contact details	101	17.1
Too busy	89	15.0
Not interested	81	13.7
Absent during screening period	53	9.0
Live too far away from testing site	49	8.3
Unwell	22	3.7
Unable to contact	14	2.4
Bad experience last time	12	2.0
Ongoing Illness / terminally illness	11	1.9
Other	10	1.7
Family commitments	7	1.2
Too old	4	0.7
Overseas (moved)	3	0.5
Total	592	100.0

A further nine participants who were unable to attend one of the AusDiab sites, were able to have blood tests taken at a local Gribbles Pathology site. Therefore, data for NSW is available on 895, giving a response rate of 60.6%. After linking the AusDiab cohort to the National Death Index in 2004, 40 participants were identified as deceased in NSW. When including the 40 deceased individuals in the overall response rate, a total of 935 of the 1539[1] NSW participants have been followed-up, with an overall response rate of 60.8%.

[1] The total number of individuals included in the 2004 sampling frame is 1539 (see Figure 1 in Section 2.1). This number differs from the number of individuals who participated in NSW in 1999 (n=1515), as the 2004 sampling frame for NSW includes participants who have moved to the NSW / ACT area, and does not include participants who moved from NSW to another state.

The survey team are currently following-up all individuals who were scheduled an appointment but did not attend the testing sites in NSW. Individuals are asked to respond to a telephone-based questionnaire, which aims to elicit self-reported diabetes status, kidney disease, heart problems, gout and fractures.

3.2 Characteristics of attendees and non-attendees

The baseline physiological and socio-demographic characteristics of participants who attended the follow-up (n=895) were compared to the characteristics of individuals who did not attend (n=583). People who attended Gribbles Pathology (n=9) were included as attendees. People who died were excluded (n=40). Attendees were more likely to have a lower BMI, lower fasting blood glucose, lower post-load glucose, lower triglycerides, higher HDL and be less likely to be classified as having diabetes, IFG or IGT. They were also more likely to speak English, more likely to be married, more likely to have completed higher levels of education, more likely to be a non-smoker and more likely to exercise. However, the two groups did not differ with respect to blood pressure, TC, LDL, sex, country of birth and Aboriginal or Torres Straight Islander status (Table 4 and Table 5).

Table 4. Physiological characteristics of attendees and non-attendees.

	Attendees	Non-attendees*	*P*-value
n	895	583	
Age	51.6 (±13.0)	51.2 (±15.7)	0.657†
Male	45.4 (406)	44.9 (262)	0.873*
Systolic blood pressure	127.8 (±17.0)	129.5 (±18.8)	0.061†
Diastolic blood pressure	70.3 (±11.1)	70.5 (±11.9)	0.715†
BMI (kg/m2)	26.5 (±4.6)	27.2 (±5.0)	0.007†
Fasting plasma blood glucose (mmol/L)	5.4 (5.0, 5.7)	5.4 (5.1, 5.9)	0.010‡
Post load plasma glucose (mmol/L)	5.7 (4.8, 6.8)	6.0 (4.9, 7.3)	0.020‡
TC (mmol/L)	5.5 (4.9, 6.2)	5.4 (4.8, 6.2)	0.185‡
HDL (mmol/L)	1.4 (±0.4)	1.4 (±0.4)	0.022†
LDL (mmol/L)	3.4 (2.9, 4.1)	3.3 (2.8, 4.0)	0.087‡
Triglycerides (mmol/L)	1.2 (0.8, 1.8)	1.2 (0.9, 1.9)	0.019‡
Diabetes Status			0.011§
· Normal glucose tolerance	77.2% (682)	70.2% (401)	
· IFG	5.4% (48)	7.9% (45)	
· IGT	10.5% (93)	10.9% (62)	
· Newly diagnosed diabetes	3.2% (28)	4.9% (28)	
· Known diabetes	3.6% (32)	6.1% (35)	

Data are mean (±sd) or % (n) or median (25th, 75th percentile);
*Data do not include deceased (n=40); †Independent samples t-test; ‡Mann-Whitney U test; §Pearson's chi-square test.
BMI – Body mass index; TC – Total cholesterol; HDL – High density lipoprotein cholesterol; LDL – Low density lipoprotein cholesterol; IFG – Impaired fasting glucose; IGT – Impaired glucose tolerance; Known diabetes was defined as participants, (i) reported receiving oral hypoglycaemic agents and/or insulin injections, or (ii) reported a history of physician-diagnosed diabetes controlled with diet therapy, and had either a fasting plasma glucose ≥7.0 mmol/l, or two-hour plasma glucose level ≥11.1 mmol/l; Newly diagnosed diabetes defined as participants not reporting physician diagnosed diabetes but had either a fasting plasma glucose ≥7.0 mmol/l, or two-hour plasma glucose level ≥11.1 mmol/l.

Table 5. Socio-demographic characteristics of attendees and non-attendees.

	Attendees	Non-attendees	*P*-value
n	895	583	
Country of birth			0.074†
· Australia / New Zealand	75.3 (674)	71.7 (418)	
· United Kingdom / Ireland	10.3 (92)	9.4 (55)	
· Other countries	14.4 (129)	18.9 (110)	
Language spoken at home			<0.001†
· English	95.8 (857)	89.9 (524)	
· Italian	0 (0)	0.2 (1)	
· Greek	0.6 (5)	0.9 (5)	
· Cantonese	1.1 (10)	3.4 (20)	
· Mandarin	0.9 (8)	0.7 (4)	
· Other	1.7 (15)	5.0 (29)	
Aboriginal / Torres Straight Islander (%)	0.4 (4)	0.7 (4)	0.719‡
Marital Status			<0.001†
· Married	79.9 (715)	71.7 (418)	
· De facto	1.7 (15)	4.3 (25)	
· Separated	2.3 (21)	3.9 (23)	
· Divorced	4.7 (42)	4.1 (24)	
· Widowed	4.8 (43)	8.7 (51)	
· Never Married	6.6 (59)	7.2 (42)	
Education			<0.001†
· Never attended school or attended primary school	3.5 (31)	4.8 (28)	
· Some high school	31.8 (285)	41.2 (240)	
· Completed high school	18.1 (162)	19.7 (115)	
· University / Technical and further education (TAFE)	46.6 (417)	34.3 (200)	
Current smokers (%)	10.0 (88)	18.9 (106)	<0.001†
Exercise			
· Sufficient (>150 minutes/day)	53.3 (475)	50.1 (289)	0.003†
· Insufficient (0-150 minutes/day)	33.9 (302)	30.5 (176)	
· Sedentary	12.9 (115)	19.4 (112)	

Data are % (n); †Pearson's chi-square test; ‡Fischer's Exact test

The results outlined in the report need to be interpreted with some caution as the results of the AusDiab study are intended to be primarily reported on a national level, due to the sampling strategy that was employed.

3.2 Diabetes and other states of glucose intolerance

For the whole NSW AusDiab population (n=1515), the age-standardised prevalence of diabetes was 7.4% in 1999. For those who attended the follow-up study (n=895), the age-standardised prevalence increased from 5.6% in 1999 to 6.1% in 2004, with men experiencing an increase in prevalence, and women experiencing a slight decrease in prevalence (Table 6).

- Table 7 shows the age-specific prevalence of IFG, IGT and diabetes in both 1999 and 2004.
- There were 30 new diabetes cases (18 males and 12 females), 34 new IFG cases (18 males and 16 females) and 50 new IGT cases (26 males and 24 females) in 2004 (Table 8).
- Table 9 indicates that of the people classified as having normal glucose tolerance in 1999, 11.6% were classified as having either IFG, IGT or diabetes in 2004, with the majority having either IFG or IGT. Of those with IFG in 1999, 50.0% were classified as having normal glucose tolerance, 10.9% were classified as having IGT and 19.6% as having diabetes in 2004. Of those with IGT in 1999, 47.3% were classified as normal, 10.8% were classified as having IFG and 14.0% were classified as having diabetes in 2004.
- Of the new diabetes cases (n=30) in 2004, 43.3% (n=13) had IGT, 30.0% (n=9) had IFG, and 26.7% (n=8) were classified as having normal glucose tolerance at baseline in 1999.
- The incidence of diabetes in people with IFG, IGT or normal glucose tolerance in 1999 was 8/1,000/year. The incidence of IFG in people with IGT or normal glucose tolerance in 1999 was 9/1,000/year. The incidence of IGT in people with IFG or normal glucose tolerance was 15/1,000/year (Table 8).
- The incidence of diabetes was 44, 30 and 2 per 1,000/year for people with IFG, IGT and normal glucose tolerance at baseline, respectively (Table 8).
- After excluding people who were diabetic at baseline, those who developed diabetes over five years were compared to those who remained non-diabetic. Individuals with incident diabetes were significantly older, had higher systolic and diastolic blood pressure, higher BMI, higher fasting and post-load blood glucose, higher TC, higher LDL, higher triglycerides, lower HDL and a higher likelihood of smoking in 1999 (Table 10).

Table 6. Age-standardised prevalence (%) of diabetes, IFG and IGT in 1999 and 2004.

	Age-standardised* prevalence (%)					
	Males		Females		Total	
	1999	2004	1999	2004	1999	2004
IFG	6.9	4.8	2.9	3.6	4.9	4.2
IGT	7.9	10.1	12.1	11.0	10.0	10.5
all diabetes	5.4	6.6	5.7	5.5	5.6	6.1

*Age-standardised to the 1999 New South Wales population using the direct method of standardisation.
IFG – Impaired fasting glucose; IGT – Impaired glucose tolerance.

Table 7. Glucose tolerance status according to age and survey year.

Age groups	n		Normal		IFG		IGT		DM	
	1999	2004	1999	2004	1999	2004	1999	2004	1999	2004
25-34	69	32	94.2 (65)	84.4 (27)	1.4 (1)	3.1 (1)	4.3 (3)	12.5 (4)	0.0 (0)	0.0 (0)
35-44	215	124	89.3 (192)	87.9 (109)	3.7 (8)	2.4 (3)	5.1 (11)	7.3 (9)	1.9 (4)	2.4 (3)
45-54	256	254	80.5 (206)	86.2 (219)	6.6 (17)	4.7 (12)	9.0 (23)	5.5 (14)	3.9 (10)	3.5 (9)
55-64	182	236	69.8 (127)	76.7 (181)	6.0 (11)	6.8 (16)	13.7 (25)	7.6 (18)	10.4 (19)	8.9 (21)
65-74	112	137	57.1 (64)	62.0 (85)	6.3 (7)	8.0 (11)	17.9 (20)	13.9 (19)	18.8 (21)	16.1 (22)
75+	49	89	57.1 (28)	50.6 (45)	8.2 (4)	2.2 (2)	22.4 (11)	24.7 (22)	12.2 (6)	22.5 (20)
Total	883	872	682	666	48	45	93	86	60	75

Data are % (n); IFG – Impaired fasting glucose; IGT – Impaired glucose tolerance.

Table 8. Annual incidence of diabetes, IFG and IGT in NSW.

1999		2004		
	n	IFG	IGT	Diabetes
IFG	46	-	23 (5)	44 (9)
IGT	93	23 (10)	-	30 (13)
Normal	664	7 (24)	14 (45)	2 (8)
Overall	803	9 (34)	15 (50)	8 (30)

Data are per 1,000 population per year (actual n over five years).
IFG – Impaired fasting glucose; IGT – Impaired glucose tolerance.
Annual incidence rates were calculated from the five-year incidence rates by applying the following formula: $(-\ln(1-S))/t$; where S is the proportion of new cases over t years and t equals the time of follow-up.
Individuals who were classified with diabetes in 1999 and then classified as having either IFG or IGT in 2004 were not included in the above calculations.

Table 9. Glucose tolerance status in 2004 according to baseline status.

1999		2004			
	n	Normal	IFG	IGT	Diabetes
Normal	664	88.4 (587)	3.6 (24)	6.8 (45)	1.2 (8)
IFG	46	50.0 (23)	19.6 (9)	10.9 (5)	19.6 (9)
IGT	93	47.3 (44)	10.8 (10)	28.0 (26)	14.0 (13)
Diabetes	59	6.8 (4)	3.4 (2)	13.6 (8)	76.3 (45)
Total	862	658	45	84	75

Data are % (n); IFG - Impaired fasting glucose; IGT – Impaired glucose tolerance

Table 10. Baseline characteristics according to whether or not diabetes developed over five years for those free of diabetes at baseline.

	Status at outcome in 2004		*P* value*
	Non-diabetic	Diabetic	
n	773	30	
Age	50.7 (±12.7)	55.6 (±12.5)	0.038†
Systolic blood pressure (mmHg)	126.6 (±16.1)	138.3 (±19.1)	<0.001†
Diastolic blood pressure (mmHg)	70.0 (±10.9)	80.4 (±9.7)	<0.001†
BMI (kg/m^2)	26.1 (±4.3)	28.8 (±4.1)	0.001†
Fasting plasma blood glucose (mmol/L)	5.3 (5.0, 5.6)	5.9 (5.5, 6.5)	<0.001‡
Post load plasma glucose (mmol/L)	5.6 (4.8, 6.5)	7.4 (6.0, 9.0)	<0.001‡
TC (mmol/L)	5.6 (±1.0)	6.3 (±1.2)	<0.001†
HDL (mmol/L)	1.5 (±0.4)	1.3 (±0.4)	0.036†
LDL (mmol/L)	3.5 (±0.9)	4.0 (±1.2)	0.002†
Triglycerides (mmol/L)	1.1 (0.8, 1.7)	1.9 (1.2, 3.5)	<0.001‡
Exercise (%)			
· Sedentary	13.0 (100)	13.3 (4)	0.243§
· Insufficient	32.6 (252)	46.7 (14)	
· Sufficient	54.4 (420)	40.0 (12)	
Smoking (%)			
· Current	9.0 (68)	20.0 (6)	0.045§
· Past	24.9 (189)	33.3 (10)	

Data are mean (±sd), median (25th, 75th percentile) or % (n).
BMI – Body mass index; TC – Total cholesterol; HDL – High density lipoprotein cholesterol; LDL – Low density lipoprotein cholesterol.
†Independent t-test; ‡Mann-Whitney U test; §Pearson's chi-square test.

3.3 Overweight and obesity

- For the whole NSW AusDiab population (n=1515), the age-standardised prevalence of obesity (BMI ≥30 kg/m^2) was 18.6% in 1999. For those who attended the follow-up study (n=895), the age-standardised prevalence of obesity increased from 18.2% in 1999 to 21.4% in 2004 (Table 11).

- Between 1999 and 2004, the proportions of individuals with a normal BMI (<25 kg/m^2) reduced and the proportion of individuals overweight (≥25 - <30 kg/m^2) remained unchanged (Table 11).

- Most age groups had a higher prevalence of obesity in 2004 compared to 1999 (Table 12).

- Mean (±sd) weight increased from 74.9 kg (±15.2) in 1999 to 76.0 kg (±16.1) in 2004, which represented a significant mean weight gain of 1.1 kg (*P*<0.001). This difference remained unchanged after adjusting for age.

- For those individuals who were normal or overweight in 1999, 18.1% (127/701) had progressed to a higher weight category by 2004. However, for those who were obese in 1999, only 7.8% had moved to a lower weight category after five years (Table 13).

Table 11. Age-standardised prevalence (%) of normal, overweight and obesity BMI categories in 1999 and 2004.

	Age-standardised* prevalence (%)					
	Males		Females		Total	
BMI categories†	1999	2004	1999	2004	1999	2004
Normal	34.3	34.4	49.1	42.6	41.8	38.6
Overweight	47.7	43.2	32.6	36.9	40.0	40.0
Obesity	18.1	22.3	18.3	20.5	18.2	21.4

*Age-standardised to the 1999 New South Wales population using the direct method of standardisation.
†Body mass index (BMI: weight / height^2) was categorised into three groups: (i) normal: BMI <25 kg/m^2; (ii) overweight ≥25 - <30 kg/m^2; and (iii) obese: ≥30 kg/m^2.

Table 12. Age-specific prevalence of normal, overweight and obesity BMI categories* for 1999 and 2004.

	n		Normal		Overweight		Obese	
Age groups	1999	2004	1999	2004	1999	2004	1999	2004
25-34	68	31	50.0 (34)	48.4 (15)	35.3 (24)	41.9 (13)	14.7 (10)	9.7 (3)
35-44	216	127	51.4 (111)	39.4 (50)	34.3 (74)	35.4 (45)	14.4 (31)	25.2 (32)
45-54	257	256	42.0 (108)	38.7 (99)	38.5 (99)	39.1 (100)	19.5 (50)	22.3 (57)
55-64	182	239	31.3 (57)	32.2 (77)	44.0 (80)	39.3 (94)	24.7 (45)	28.5 (68)
65-74	110	139	29.1 (32)	28.8 (40)	47.3 (52)	49.6 (69)	23.6 (26)	21.6 (30)
75+	50	87	40.0 (20)	39.1 (34)	46.0 (23)	37.9 (33)	14.0 (7)	23.0 (20)
Total	883	879	362	315	352	354	169	210

Data are n (%). *Body mass index (BMI: weight / height^2) was categorised into three groups: (i) normal: BMI <25 kg/m^2; (ii) overweight ≥25 - <30 kg/m^2; and (iii) obese: ≥30 kg/m^2.

Table 13. BMI categories in 2004 according to baseline status.

BMI categories* 1999		BMI categories* 2004		
	n	Normal	Overweight	Obese
Normal	351	78.9 (277)	20.5 (72)	0.6 (2)
Overweight	350	9.4 (33)	75.4 (264)	15.1 (53)
Obese	166	0.6 (1)	7.2 (12)	92.2 (153)
Total	867	311	348	208

Data are n (%). *Body mass index (BMI: weight / height^2) was categorised into three groups: (i) normal: BMI <25 kg/m^2; (ii) overweight ≥25 - <30 kg/m^2; and (iii) obese: ≥30 kg/m^2.

3.4 Dyslipidemia

- For those who attended the follow-up study, the age-standardised prevalence of having abnormal lipid levels decreased for TC (≥5.5 mmol/L), LDL (≥3.5 mmol/L) and triglycerides (≥2.0 mmol/L) and increased for HDL (≤1.0 mmol/L) in 2004.

- In 2004, 13.7% of participants (15.2% for males and 12.3% for females) reported taking lipid-lowering medication, compared with 8.4% of participants reporting medication use in 1999 (Table 14).

- Table 15 indicates that 18.4% of those with a TC <5.5 mmol/L progressed to a higher TC (≥5.5 mmol/L) category and 44.8% moved from a higher to a lower TC category in 2004.

- There was a significant mean decrease of 0.35 mmol/L for TC and 0.31 mmol/L for LDL between 1999 and 2005. Age did not significantly influence these changes. A small mean reduction was observed for HDL and triglycerides remained unchanged (Table 16).

Table 14. Age-standardised prevalence (%) of higher lipid levels and lipid-lowering medication use in 1999 and 2004.

	Age-standardised* prevalence (%)					
	Males		Females		Total	
	1999	2004	1999	2004	1999	2004
TC ≥5.5 mmol/L	50.6	34.5	48.8	36.1	49.7	35.4
LDL ≥3.5 mmol/L	48.5	36.5	36.8	28.2	42.5	32.3
HDL ≤1.0 mmol/L	11.6	22.6	4.0	5.8	7.7	14.0
Triglycerides ≥2.0 mmol/L	18.7	17.8	16.5	13.9	17.6	15.8
Any lipid abnormality†	63.8	60.1	56.5	45.7	60.1	52.7
Taking lipid-lowering medication	7.7	15.2	9.1	12.3	8.4	13.7
Any lipid abnormality† or taking lipid-lowering medication	69.6	68.3	60.6	53.8	65.0	60.9

TC – total cholesterol; LDL – low-density lipoprotein cholesterol; HDL – high-density lipoprotein cholesterol.
*Age-standardised to the 1999 New South Wales population using the direct method of standardisation.
†Any lipid abnormality includes individuals who had any of: (i) TC ≥5.5 mmol/L, (ii) LDL ≥ 3.5 mmol/L, (iii) HDL ≤ 1.0 mmol/L, (iv) triglycerides ≥ 2.0 mmol/L, where individual lipid cut-offs were based on recommendations by the National Heart Foundation (9, 10).

Table 15. Proportion of individuals with a total cholesterol ≥5.5 mmol/L in 2004 according to baseline status.

TC 1999		TC 2004	
	n	<5.5 mmol/L	≥5.5 mmol/L
<5.5 mmol/L	413	81.6 (337)	18.4 (76)
≥5.5 mmol/L	467	44.8 (209)	55.2 (258)
	880	546	334

Data are % (n).

Table 16. Change in mean values for lipids between 1999 and 2004.

Lipid	Mean values		Mean difference	*P*-value	Mean difference adj age*	*P*-value*
	1999	2004				
TC	5.6 (±1.0)	5.2 (±0.9)	-0.35	<0.001	-0.39	<0.001
LDL	3.5 (±0.9)	3.2 (±0.9)	-0.31	<0.001	-0.32	<0.001
HDL	1.4 (±0.4)	1.4 (±0.4)	-0.03	<0.001	-0.04	<0.001
Triglycerides	1.2 (0.8, 1.8)†	1.2 (0.8, 1.7)†	-0.002‡	.891	-0.033	0.027

Data are mean (±SD); TC – total cholesterol; LDL – low-density lipoprotein cholesterol; HDL – high-density lipoprotein cholesterol.
*Adjusted for age; †Median (25th and 75th percentiles); ‡Difference in the mean logarithmic values between 1999 and 2004. Corresponding *P*-values calculated on logarithmic transformed values.

3.5 Hypertension

- For the whole NSW AusDiab population (n=1515), the age-standardised prevalence of hypertension was 28.1% in 1999. In the follow-up study, the age-standardised prevalence decreased from 26.7% to 23.1% (Table 17).

- The prevalence of self-reported medication use for blood pressure increased from 14.2% to 16.9% (Table 17), with increases noted for most age groups (Table 18).

- The most marked decrease in hypertension prevalence occurred in participants aged 65-74 years (Table 18).

- For those classified with normotension in 1999, 11.1% (68/613) were classified with hypertension in 2004. For those classified with hypertension in 1999, 22.6% (58/257) were classified with normotension in 2004 (Table 19).

- There was a mean 9.1 mmHg decrease in systolic blood pressure ($P<0.001$) and mean 4.0 mmHg decrease in diastolic blood pressure ($P<0.001$) between 1999 and 2004. After accounting for age the difference noted for systolic blood pressure was slightly more marked (Table 20).

Table 17. Age-standardised prevalence (%) of hypertension and antihypertensive medication use in 1999 and 2004.

	Age-standardised* prevalence (%)					
	Male		Female		Total	
	1999	2004	1999	2004	1999	2004
Normal blood pressure (<140/90 mmHg)†	74.5	77.8	72.2	76.0	73.3	76.9
Hypertension‡	25.5	22.2	27.8	24.0	26.7	23.1
Taking antihypertensive medication§	11.0	14.7	17.2	19.1	14.2	16.9

*Age-standardised to the 1999 New South Wales population using the direct method of standardisation.
†Normal blood pressure defined as having a blood pressure <140/90 mmHg and not taking medication.
‡Hypertension defined as either having a blood pressure ≥140/90 mmHg or taking antihypertensive medication.
§Antihypertensive medication use based on self-report.

Table 18. Age-specific prevalence of hypertension and antihypertensive medication use in 1999 and 2004.

	n		Normal blood pressure†		Hypertension‡		Antihypertensive use§	
Age groups	1999	2004	1999	2004	1999	2004	1999	2004
25-34	73	34	95.9 (70)	97.1 (33)	4.1 (3)	2.9 (1)	1.4 (1)	0.0 (0)
35-44	216	124	94.0 (203)	90.3 (112)	6.0 (13)	9.7 (12)	3.2 (7)	5.7 (7)
45-54	257	253	76.7 (197)	82.6 (209)	23.3 (60)	17.4 (44)	11.7 (30)	13.8 (35)
55-64	183	238	60.7 (111)	69.3 (165)	39.3 (72)	30.7 (73)	17.5 (32)	24.5 (58)
65-74	111	139	35.1 (39)	46.8 (65)	64.9 (72)	53.2 (74)	45.0 (50)	39.0 (53)
75+	50	87	18.0 (9)	26.4 (23)	82.0 (41)	73.6 (64)	40.0 (20)	58.3 (49)
Total	890	875	629	607	261	268	140	202

Data are % (n). Percentages may not be exact due to missing data.
†Normal blood pressure defined as having a blood pressure <140/90 mmHg and not taking medication.
‡Hypertension defined as either having a blood pressure ≥140/90 mmHg or taking antihypertensive medication.
§Antihypertensive medication use based on self-report.

Table 19. Proportion of individuals classified with hypertension in 2004 according to baseline hypertensive status.

1999		2004	
	n	Normotension†	Hypertension‡
Normotension†	613	88.9 (545)	11.1 (68)
Hypertension‡	257	22.6 (58)	77.4 (199)
Total	870	603	267

Data are % (n).
†Normal blood pressure defined as having a blood pressure <140/90 mmHg and not taking medication.
‡Hypertension defined as either having a blood pressure ≥140/90 mmHg or taking antihypertensive medication.

Table 20. Change in mean values for blood pressure between 1999 and 2004.

Blood pressure	Mean values		Mean difference	*P*-value	Age adjusted mean difference†	*P*-value†
	1999	2004				
Systolic	127.8 (±17.0)	118.7 (±18.2)	-9.1	<0.001	-12.1	<0.001
Diastolic	70.3 (±11.1)	66.4 (±10.0)	-4.0	<0.001	-4.3	<0.001

Data are mean (±sd); † Mean difference adjusted for age, with the corresponding *P*-value.

4. Key Findings

The key findings are summarised as follows:

- Of the 1478 participants from the baseline study who were eligible for follow-up testing in NSW, 895 (60.6%) individuals attended the AusDiab follow-up survey in 2004.

- The overall incidence of diabetes was 8/1,000 population/year. The majority of new diabetes cases in 2004 were previously classified as having either IGT or IFG.

- The incidence of IFG was 9/1,000 population/year. The incidence of IGT was 15/1,000 population/year.

- There was a mean weight gain of 1.1 kg over five years, with 18.1% of individuals not previously obese progressing to a higher weight category. For those who were obese in 1999 only 7.8% moved to a lower weight category after five years.

- The mean values for total cholesterol (TC) and low-density lipoprotein cholesterol (LDL) significantly improved over the five years with mean reductions of 0.35 mmol/L and 0.31 mmol/L respectively. There was a small mean reduction of 0.03mmol/L of high-density lipoprotein cholesterol (HDL), whereas triglyceride levels remained unchanged.

- The prevalence of self-reported lipid-lowering medication use increased from 8.4% in 1999 to 13.7% in 2004.

- Between 1999 and 2004, there was a mean decrease of 9.1 mmHg in systolic blood pressure and a mean decrease of 4.0 mmHg for diastolic blood pressure.

- Antihypertensive use increased from 14.2% in 1999 to 16.9% in 2004.

Conclusions

The incidence of diabetes at 8/1,000/year was similar to other studies. The incidence of IFG was 9/1,000/year and the incidence of IGT was 15/1,000/year. On average, people gained 1.1 kg over five years. More people reported taking both lipid-lowering and antihypertensive medication in 2004 compared with 1999. Change in medication use may be one factor that explains the improvement in TC, LDL and blood pressure profiles.

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Appendix A - Testing sites and dates

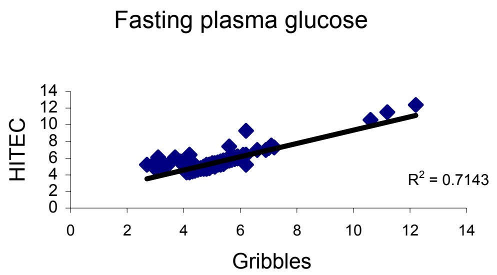
Site	Date of testing 2004
Grays Point	26th – 31st October
Grays Point Community Centre	
118 Grays Point Road, Grays Point	
Canberra	2nd – 3rd November
City Health Centre, Diabetes Service	
Moore and Alinga St, Canberra	
Hurstville	5th – 9th November
lllawarra Catholic Club	
13 - 17 Woodville St, Hurstville	
Orange	13th – 15th November
Orange City Bowling Club	18th – 21st November
61 Warrendine Street, Orange	
Berkeley Vale	24th – 3oth November
Berkeley Vale Sports Club	
3-7 Berkeley Road, Glenning Valley	
West Pennant Hills	3rd – 9th December
Castle Hill Guide Hall	
52 Bounty Avenue, Castle Hill	
Auburn	12th – 15th December
Auburn / Lidcombe RSL Youth Centre	
Church Street, Lidcombe	

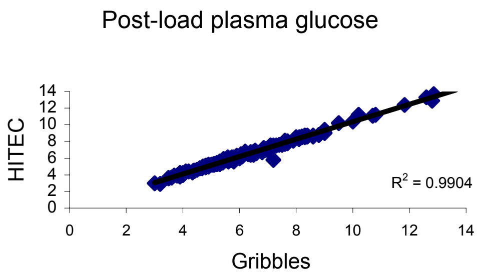
Appendix B – Abbreviations

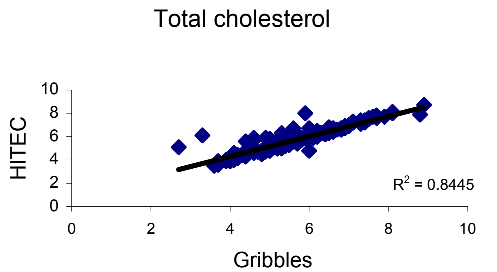
AusDiab	Australian Diabetes Obesity and Lifestyle Study
BMI	Body mass index
HDL	High density lipoprotein cholesterol
IFG	Impaired fasting glucose
IGT	Impaired glucose tolerance
LDL	Low density lipoprotein cholesterol
NSW	New South Wales
OGTT	Oral glucose tolerance test
SD	Standard deviation
TC	Total cholesterol

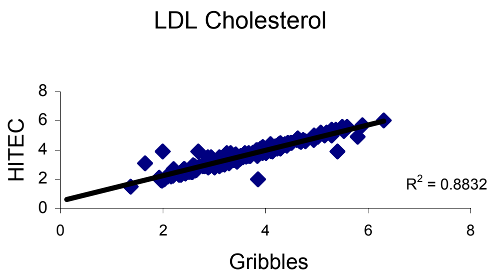
Appendix C – Comparison of survey laboratory methods

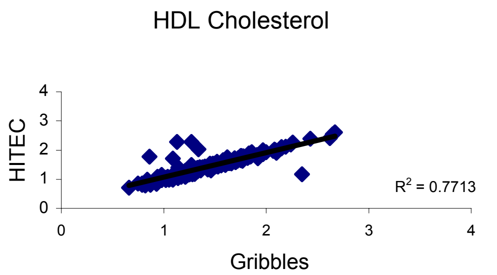
The laboratory methods used in 1999 (HITECH Pathology, Melbourne, Australia) and 2004 (Gribbles Pathology, Melbourne, Australia) were compared. A random selection of frozen blood samples that were collected during the first AusDiab study in 1999 were re-analysed in 2004 by Gribbles Pathology. The following figures outlines the results obtained from the original analysis (HITECH Pathology) in 1999 plotted against the results obtained from Gribbles. The triglyceride values are plotted on a logarithmic scale. The data suggest that the laboratory methods used in 1999 and 2004 were comparable.

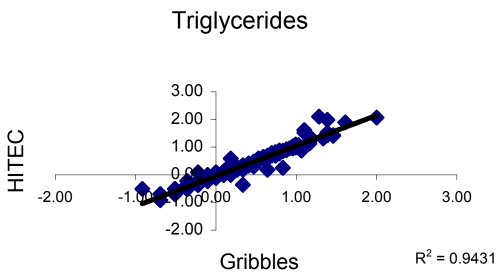












Appendix D – AusDiab Methods paper

Diabetes Research and Clinical Practice 57 (2002) 119–129
DIABETES RESEARCH AND CLINICAL PRACTICE
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The Australian Diabetes, Obesity and Lifestyle Study (AusDiab)—methods and response rates

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Abstract

The Australian Diabetes, Obesity and Lifestyle Study (AusDiab) addresses the urgent need for data on diabetes prevalence, risk factors and associated conditions in Australia. Here we describe the methods used and the response rates obtained. AusDiab was a population-based cross-sectional survey of national diabetes mellitus prevalence and associated risk factors in people aged ≥ 25 years, conducted between May 1999 and December 2000 in the six states and the Northern Territory of Australia. The study involved an initial household interview, followed by a biomedical examination that included an oral glucose tolerance test (OGTT), standard anthropometric tests, blood pressure measurements and the administration of questionnaires. Of the 20 347 eligible people (aged ≥ 25 years and resident at the address for ≥ 6 months) who completed a household interview, 11 247 (55.3%) attended for the biomedical examination. Of those who completed the biomedical examination 55.1% were female. Comparisons with the 1998 Australian population estimates showed that younger age responders were under-represented at the biomedical examination, while the middle-aged and older age groups were over-represented. Weighting of the AusDiab data for age and gender have corrected for this bias. AusDiab, which is the largest national diabetes prevalence study undertaken in a developed nation to have used an OGTT, provides a valuable national resource for the study of the prevalence and possible causes of diabetes, as well as identifying possible risk factors that may lead to diabetes. Furthermore, it generates the baseline data for a prospective 5-year cohort study. The data will be important for national and regional public health and lifestyle education and health promotion programs.

Keywords: AusDiab; Response rates; Diabetes survey; Australia; Diabetes prevalence

1. Introduction

Globally, the prevalence of diabetes, particularly Type 2 diabetes is rapidly increasing [1].

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Indeed, it has been predicted that the global figure of people with diabetes will rise from current levels of about 150 million in 2000 to 300 million by 2025 [2]. However, with the exception of the USA [3], nationally representative, population based diabetes prevalence data among developed nations is scarce. In particular, few studies have involved an oral glucose tolerance test (OGTT).

In Australia, estimates of diabetes prevalence and other categories of glucose intolerance are confined to studies conducted 10–20 years ago on a small sample of residents from a rural town in Western Australia [4]. Most recent estimates of diabetes prevalence in Australia have relied on self-reported data, but since Type 2 diabetes can be asymptomatic for many years before it is diagnosed in a clinical situation, reliance on self-reported information invariably contributes to an underestimation of the true prevalence. Furthermore, such studies fail to provide information on the extent of other states of glucose intolerance, which are known to substantially increase risk of future diabetes.

To address the urgent need for more definitive data on the true current prevalence of diabetes and its associated risk factors in Australia, the Australian Diabetes, Obesity and Lifestyle Study (AusDiab) was a cross-sectional study involving a standard OGTT conducted during 1999–2000 in all Australian States and the Northern Territory. The present paper provides a detailed description of the survey methods including the design, sampling techniques and survey protocols. Data on weighting of the sample, response rates and statistical techniques are also presented. The survey methods conform to those recommended by the World Health Organisation (WHO) [5], and the study was approved by the International Diabetes Institute ethics committee.

The AusDiab study aimed to determine the national prevalence of diabetes and other selected non-communicable diseases and their risk factors in a representative sample of adults aged 25 years and over from each of the states and the Northern Territory of Australia.

More specifically, the objectives of the study were to:

1. estimate the national and regional prevalence of diabetes and other forms of abnormal glucose tolerance;
2. estimate the prevalence of the cardiovascular risk factors within the Metabolic Syndrome, including obesity, hypertension, and lipid profile abnormalities;
3. assess the distribution and relationships of the cardiovascular risk factors indicated above;
4. assess temporal trends in risk factor prevalences with reference to previous Australian surveys;
5. describe health knowledge and attitudes and utilization of health services, and
6. provide baseline data for longitudinal cohort studies.

2. Methods

2.1. Target population/eligibility requirements

Non-institutionalised adults aged 25 years and over residing in private dwellings in each of the six states and the Northern Territory of Australia were included in the survey if they had resided permanently at the address for a minimum of 6 months prior to the survey. Persons with physical or intellectual disabilities that precluded participation in the study were not included.

2.2. Sampling frame

A stratified cluster sampling method was used, involving seven strata (six states and the Northern Territory) and clusters based on census collector districts (CDs—the smallest geographic unit defined by the Australian Bureau of Statistics at each census, with an average of 225 dwellings each). Within each state, 6 CDs were randomly selected with a selection probability proportional to the population size (population aged over 25 years). Due to the logistic and economic constraints of the survey, and to avoid the bias of including an unrepresentative number of high prevalence groups, the following exclusion criteria were adopted:

1. CDs containing fewer than 100 persons aged 25 years and over
2. CDs that formed part of a statistical local area that was classified as 100% rural according to 1996 census data [6]
3. CDs that contained more than 10% indigenous population.

Of the total pool of CDs available (34 410), 4141 CDs (12%) were excluded from selection on these grounds. From the excluded CD's, 762 (18.4%) had $>10\%$ indigenous population, 1464 (35.4%) were rural, 1100 (26.6%) had <100 persons aged $\geqslant 25$ years, while 815 (19.7%) had more than one factor of the exclusion criteria. The three exclusion categories meant that the total eligible population (adults aged $\geqslant 25$ years) was reduced by 6.44% from 11 341 070 to 10 610 855. This comprised 241 931 (33.1%) adults from CDs that had $>10\%$ indigenous population, 349 716 (47.9%) adults from CDs that were rural, 74 723 (10.2%) adults from CDs that had <100 people aged $\geqslant 25$ years and 63 845 (8.7%) adults from CDs that had more than one factor of the exclusion criteria.

2.3. Sample size determination

The sample size was selected based on precision of estimates to identify a national diabetes prevalence of 7.0% (an estimation based on results of previous surveys, and the expectation that the diabetes rate had increased over time). As a secondary objective of the study was to deliver useful state-specific prevalence estimates, the sampling frame was stratified at the state level. With very little loss of efficiency, an accurate national estimate can be obtained from weighted samples of equal size from the six states and the Northern Territory. Accounting for the clustering of the survey design, a sample size of 10 500 (1500 per state) was predicted to provide 95% confidence intervals of 6.2–7.8, around a diabetes estimate of 7.0%. This level of precision was regarded as acceptable, and the sample size was considered achievable and within the funding constraints of the survey. It should be noted however, that the sample size was calculated for total diabetes prevalence only and would be expected to have limited power to describe the prevalence of type 1 diabetes in this sample.

2.4. Sample selection

It was calculated that 6 CDs were required to provide the required sample size (1500 per state) within each state. Following an initial field visit, if the CD was considered inappropriate for sampling in that location, the selected CD was replaced with another randomly selected CD from the same state. Replacements occurred in seven instances during the course of the survey, for the following reasons:

1. The low population density of the CD made it economically and logistically impossible to conduct the survey activities within the allocated timeframe (3 CDs)
2. The area selected was predominantly an industrial/business zone (2 CDs)
3. No eligible 'neighbouring' CD was available (see below) (1 CD)
4. The area had been recently involved in a large-scale health survey, including diabetes testing (1 CD).

After the first three sites had been surveyed, it became clear that a single CD would not provide the required sample size at each location surveyed. Clusters were subsequently formed by combining the randomly selected index CD and its largest adjoining neighbours to achieve a minimum cluster size of 250 participants. The final sample comprised 3 single CDs, 22 pairs of CDs, 16 triplets and 1 quad.

2.5. Survey protocol and procedures

The AusDiab survey activities occurred over a 21-month period between May 1999 and December 2001. Approximately 2 months were allocated to the collection of data in each state and the Northern Territory. The AusDiab survey activities were divided into two phases—the household interview and the biomedical examination.

2.5.1. Household census and interview

Following a local media advertising campaign involving news items in local community newspapers and local radio and/or television, all private dwellings within the sampled cluster received a hand-delivered (non-addressed) letter informing residents about the survey and advising that an AusDiab interviewer would visit to conduct the household interview. A brochure describing the study objectives, the interview and examination process, and study confidentiality was supplied in the initial contact letter. This brochure was provided only in English.

The first visit by the interviewer occurred approximately 3 days after the letter had been delivered. If the interviewer could not make contact with household members, a letter was left requesting the household to telephone a toll-free number to arrange a suitable interview time. The interviewers made a minimum of 2 visits and up to 5 visits before a household was classified as a non-contact.

Where possible, at each participating household a personal interview was conducted with every adult member aged 25 years and over who met the eligibility requirements. The interview ascertained marital status, level of education, date and country of birth, language spoken at home and history of diabetes or high blood sugar levels. In some instances, adult household members were unable to answer for themselves because of old age, illness, intellectual disability or difficulty with the English language. In these cases, a responsible 'proxy' was interviewed on their behalf. There were no provisions for interviews to be conducted in languages other than English. In order to obtain a personal interview with all eligible household members, interviewers made appointments to visit as often as was necessary to the household. In a small number of cases interviews were conducted over the telephone with the Household Survey Coordinator.

At the completion of the interview, all household members aged 25 years or older were invited to attend a local testing site for the biomedical examination. Participants were provided with a brochure explaining the biomedical examination procedures, together with the self-administered SF-36 General Health and Well-Being questionnaire, which they were asked to complete and bring to their biomedical examination appointment.

2.5.2. Biomedical examination

The biomedical examination was conducted at a local test site on weekdays (except Friday) and weekend days over an 8-day period in each sampled area. Local survey sites included community centres, scout headquarters, sporting venues, church halls and schools. Survey activities at the testing site commenced at 7:00 a.m. and typically finished at 2:00 p.m. On average, approximately 40 participants attended daily.

All responders gave written informed consent to participate in the survey upon arrival at the testing site. The AusDiab biomedical examination protocol followed closely the WHO recommended model for diabetes and other non-communicable disease field surveys [5,7]. The components of the biomedical examination are shown in Table 1. Following the initial collection of the fasting blood sample, an OGTT was performed on all participants, except those on insulin or oral hypoglycaemic drugs or those who were pregnant. The OGTT was performed according to WHO specifications. Participants moved through the biomedical examination procedures in a circuit-like manner that took approximately 2.5–3 h to complete. The SF-36 and dietary questionnaires were self-administered, while all other questionnaires were interviewer administered. All data from the participant record forms were entered both electronically and manually.

3. Results

3.1. Survey response

Response rates to the household interview and the biomedical examination are shown in Fig. 1. In total, the AusDiab interviewers approached 25 984 households in the 42 selected clusters. Of these, 6769 (26%) were classified as non-contacts. Reasons for non-contact (and hence non-participation) in the household interview included language difficulties (318 households), no access gained to the residence (e.g. because of dangerous dogs, security fences) (941), the householders not being contactable despite several attempts (5358), and other reasons such as drunkenness or disability of the householders (152).

Of the 19 215 residential properties where contact was achieved, 1095 were excluded because none of the occupants met the residency criteria of the survey, and a further 991 were excluded because all of the residents in the household were less than 25 years of age. Of the remaining 17 129 eligible households, 5178 refused to be interviewed and 472 were away for the duration of the study period, giving rise to a total of 11 479 households (70.2%) where an interview was achieved. Reasons for refusal included health concerns (486, 9.4%), being unable to attend because of work commitments (1159, 22.4%), feeling they were too old to participate (368, 7.1%), medical problems (1317, 25.4%), and 'other' reasons (1848, 35.7%).

Assuming that the proportion of ineligible households was similar between the contacted (2086/19 215 = 10.9% ineligible) and the non-contacted households, 49.6% (11 479/23 163) of eligible households participated in the household interview. The denominator here (23 163) is calculated as all private dwellings (25 984) minus all ineligible households (2821, which is comprised of

Table 1
Variables assessed within AusDiab

Category	Variable	Measurement instrument
Demographic characteristics	Age, sex, ethnicity	Household interview and interviewer-administered questionnaires at survey site
	Socio-economic status (education, occupation, income)	
	Diabetes status	
Medical and family history	Family history (diabetes)	Interviewer-administered questionnaires at survey site
	Chronic health conditions (cardiovascular disease, gout)	
	Women's health	
Life-style related factors	General health and well-being	SF-36 Questionnaire
	Alcohol/tobacco	Interviewer-administered questionnaires at survey site
	Physical activity	
	Diet	Anti-Cancer Council of Victoria Dietary Questionnaire (self-administered)
Health-behaviour related factors	Health knowledge, attitudes and practice data	Interviewer-administered questionnaires at survey site
	Health service utilisation patterns	
Physical measurements	Height	Stadiometer
	Weight	Beam balance scales
	Waist and hip circumference	Tape measure
	Body fat determination	Bioimpedance
	Blood pressure	Dinamap/mercury sphygmomanometer
	12-lead ECG	
Blood measurements (fasting)	Blood glucose	Glucose oxidase
	Blood lipids	Enzymatically—Olympus AU600 analyser
	HbA_{1c}	Boronate affinity high performance liquid chromatography
Urine measurements (spot morning sample)	Albumin	Immunoturbidimetric method—Olympus AU600 analyser
	Creatinine	Olympus AU600 analyser

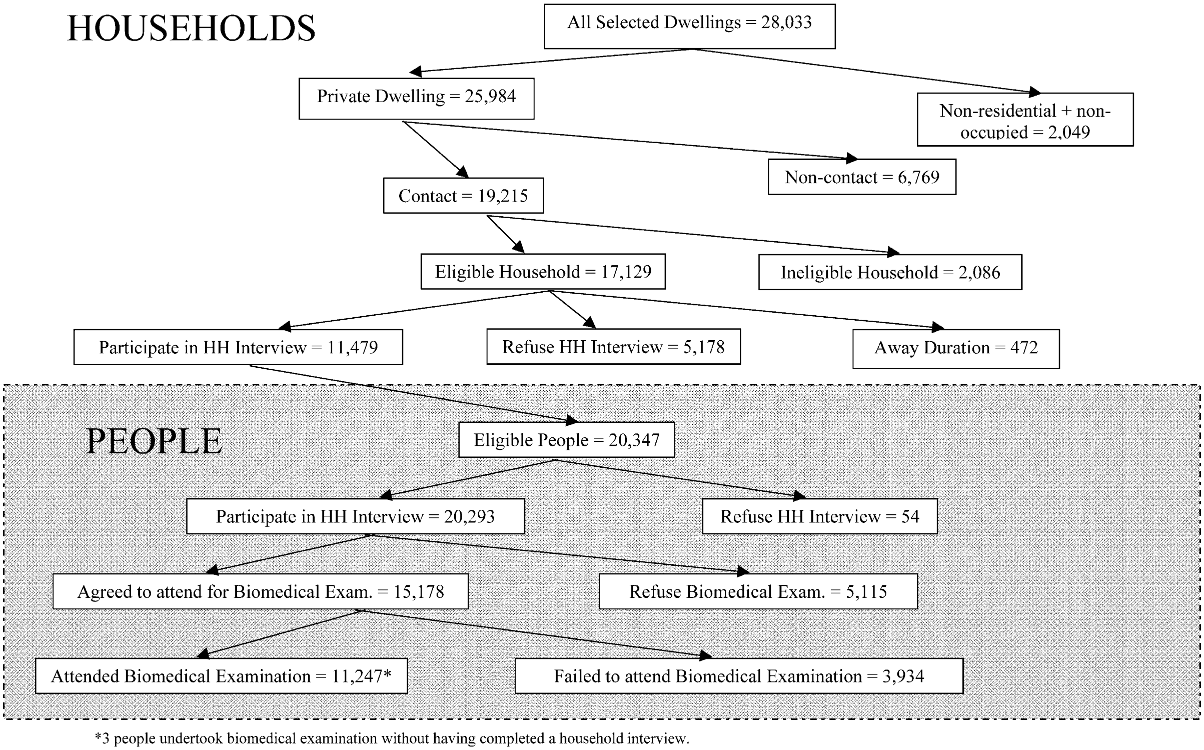

Fig. 1. Flowchart of households and persons selected to participate in AusDiab.

2086 contacted ineligible households, plus 735, which is an equivalent percentage of non-contacted ineligible households). This response rate is a conservative estimate, as more of the non-contacted households are likely to be unoccupied or have fewer occupants than contacted households.

In the 17 129 households that were confirmed as containing at least one eligible participant, 20 347 eligible adults were interviewed. Of those who participated in the household interview, 11 247 (55.3%) took part in the biomedical examination. This response rate for the biomedical examination ranged from 49.5% in Queensland and 49.6% in South Australia to 61.8% in Western Australia (Table 2). Assuming that the numbers of eligible adults residing in the 5178 households that refused the household interview was the same as in those which participated, and combining the household response rate (11 479/17 129 = 67%) with the biomedical examination response rate (11 247/20 347 = 55.3%) the overall response rate can be estimated to be 37%.

3.2. Profile of responders and weighting of the survey sample

To account for the clustering and stratification of the survey design, and to adjust for non-response, the data have been weighted to match the age and gender distribution of the 1998 estimated residential population of Australia aged over 25 years [8]. The weighting factor is based on the probability of selection in each cluster. The number of males and females in each cluster aged 25 years and over identified in the 1996 census was used to calculate the probability of selection in each cluster. The weight was then calculated based on the probability of selection, adjusted to reflect the age and sex structure of the 1998 estimated residential population over the age of 25. Groups based on age deciles and gender defined the weighting variable. As there are two distinct populations in our sample—one who participated in the household interview and a subset of this population who attended the biomedical examination, two weighting factors have been applied, one to all responders to the biomedical examination and another to all responders to the household interview.

Among the responders to the biomedical examination ($n = 11\,247$), 44.9% were male, with the mean age being 51.5 years (Table 3). This compares to 49.0% male in the 1998 Australian population, and a mean age in the 1996 census [6] over 25 years of 48.1 years. Among the non-responders ($n = 9049$), 51.2% were male and the mean age was 47.7 years. Weighting of the sample to the estimated 1998 residential Australian population corrected the gender and age bias, with 49.0% (95% CI, 47.9–50.1) of the weighted responders to the biomedical examination being male, and the mean age being 48.2 years (95% CI, 46.6–49.9).

Table 4 provides a comparison between responders and non-responders to the biomedical examination for both unweighted and gender and age-adjusted estimates, with respect to various demographic characteristics. For the crude, unadjusted estimates, significant differences were observed for percent married, the percentage of English speaking participants, the percent born in the UK, and the percentage who suspected they had diabetes, but no differences were noted for the percentage born in Australia, the percentage born outside the UK or Australia, the percentage who had completed the highest year of school, and the percentage who had ever been told they had diabetes. Adjustment for age and gender rectified the difference between responders and non-responders for the percentage married, but differences were still observed in the percentage who suspected that they had diabetes, the percent born in the UK and the percentage of English speakers. Additionally, after adjustment for age and gender, the percentage who had completed the final year of high school, technical education or University was higher for responders.

4. Discussion

AusDiab is the largest cross-sectional study of the prevalence of diabetes and its precursors ever performed in a developed nation. Through its capacity to provide the first definitive data on the true magnitude of the diabetes epidemic in Australia, AusDiab will not only be a valuable resource for health care planners in Australia, but will also serve as an important research tool for the study of diabetes and associated diseases on a longitudinal basis.

The AusDiab experience provides a valuable insight into the execution of population-based,

Table 2
Response rates of eligible residents to the biomedical examination by state/territory

State/Territory[a]	Eligible residents (n)	Respondents to household interview (n)	Respondents to biomedical examination (n)	Biomedical examination response rate (%)[b]
VIC	2396	2391	1434	59.8
WA	2527	2485	1561	61.8
NSW	2719	2717	1515	55.7
TAS	3339	3339	1848	55.3
SA	3618	3618	1796	49.6
NT	2446	2446	1459	59.6
QLD	3302	3297	1634	49.5
Total	20 347	20 293	11 247	55.3

[a] VIC = Victoria, WA = Western Australia, NSW = New South Wales, TAS = Tasmania, SA = South Australia, NT = Northern Territory, QLD = Queensland.

[b] Calculated as biomedical examination responders as a percentage of eligible residents.

Table 3
Response rates of eligible residents to the biomedical examination by age and gender

Gender/age group	Eligible residents (n)[a]	Respondents to household interview (n)[a]	Respondents to biomedical examination (n)[a]	Biomedical examination response rate (%)[b]
Male 25–34	1757	1747	590	33.6
Male 35–44	2342	2331	1093	46.7
Male 45–54	2290	2281	1345	58.7
Male 55–64	1516	1515	928	61.2
Male 65–74	1125	1122	731	65.0
Male 75+	677	677	362	53.5
Female 25–34	1894	1890	803	42.4
Female 35–44	2510	2503	1465	58.4
Female 45–54	2355	2352	1546	65.6
Female 55–64	1649	1647	1096	66.5
Female 65–74	1286	1285	837	65.1
Female 75+	927	927	451	48.7

[a] Nineteen eligible people refused to give their age and are thus missing from this table, of whom 16 were respondents to the household interview, and none were respondents to the biomedical examination.

[b] Calculated as biomedical examination responders as a percentage of eligible residents.

cross-sectional surveys involving the use of an OGTT. Since AusDiab required careful consideration of the logistics required to achieve a national sample within the funding and timeframe constraints imposed, particular emphasis was given to the establishment of a study design that reflected the ‘best available’ model. This extensive 12-month planning process was crucial to the successful implementation of the study.

Several aspects of the methods used in sample selection and the study design of AusDiab warrant further discussion. First, the inclusion criteria contained only those CDs that contained less than 10% indigenous population. Existing data provide clear evidence of a very high prevalence of diabetes among the indigenous population in Australia [9]. To overcome the chance selection of one or more CDs with a large proportion of indigenous people, and thus minimize the potential bias introduced to the national and state diabetes estimates, we considered it more practical to restrict the inclusion criteria to those CDs likely to contain smaller proportions of indigenous people rather than account for any potential bias at the analysis stage. Furthermore, this approach was considered important for the operations of the study, since aspects such as questionnaire design would have required extensive modifications to reflect the cultural differences. It is unlikely that this restriction would have impacted greatly on the generation of national estimates since the indigenous population is numerically a very small minority group in Australia ($\approx 2\%$ of the total Australian population), and indeed, represented only 0.8% of the total AusDiab sample. Preparations are presently underway to address these issues through a survey that will employ similar survey methods used within AusDiab in urban indigenous Australians living in Darwin, Northern Territory.

The decision to sample equal numbers from each stratum reflects a compromise between the primary and secondary objectives of the survey. It is probable that a study design that sampled from the states proportional to their size would have been more efficient in terms of providing a more accurate national diabetes prevalence estimate, however accurate estimates for all states (in particular the smaller states) would have been compromised. Since weighting of the data prior to the analysis stage enables us to allow for over-representation of the smaller states and under-representation of the larger states, it is unlikely that our primary objective was compromised unduly by this decision.

Table 4
Comparison between biomedical examination responders and non-responders, both unweighted, and age and gender-adjusted to the 1998 estimated residential population aged over 25 years

Characteristic	Responders to biomedical exam. (unweighted)	Non-responders to biomedical exam. (unweighted)	Responders (age and gender adjusted to 1998 population[a])	Non-responders (age and gender adjusted to 1998 population[a])
Married	71.5 (68.8–74.2)	67.0 (64.4–69.5)	68.5 (65.5–71.5)	67.6 (65.0–70.2)
Country of birth: Australia	76.0 (72.9–79.1)	77.1 (73.8–80.5)	77.6 (74.6–80.6)	76.7 (73.3–80.1)
Country of birth: UK	11.3 (9.7–12.8)	8.7 (7.2–10.2)	10.3 (8.9–11.7)	8.8 (7.3–10.4)
Country of birth: Other	12.7 (10.2–15.2)	14.1 (10.9–17.3)	12.1 (9.7–14.5)	14.4 (11.1–17.7)
Language spoken: English	96.0 (94.6–97.4)	93.7 (91.2–96.3)	96.1 (94.9–97.4)	93.6 (91.0–96.2)
Education: completed high school/university/technical education	55.8 (51.4–60.1)	51.7 (46.4–57.1)	58.2 (54.0–62.4)	51.3 (46.0–56.6)
Ever told have DM?	6.4 (5.7–7.1)	6.2 (5.2–7.1)	5.9 (5.3–6.5)	6.4 (5.4–7.3)
Suspect have DM?	1.5 (1.3–1.7)	0.5 (0.4–0.7)	1.5 (1.3–1.7)	0.5 (0.4–0.7)

Estimates are percentages (95% CI).
[a] June 30, 1998 Australian population [8].

It is also noted that, due to the exclusion criteria of the study, the results may not be generalisable to either the indigenous population or the rural population of Australia. The primary aim of the study, however, was to provide estimates which were accurate for the Australian population over 25 years as a whole and these exclusion criteria should not significantly affect that aim.

The response rates to AusDiab can be interpreted in several ways. In many studies where a defined population is used as the sample pool, an absolute response rate can be accurately calculated. For example, when using an electoral role in the sample selection, the number of residents in each household is accurately known, allowing the demographic profile of both the non-responders and the responders to be calculated. In AusDiab, the sample pool was comprised of households in CDs based on the 1996 Australian census, conducted 2 years prior to commencement of the AusDiab survey. An accurate estimate of the number of residents in households where contact was not achieved, as well as the age and gender profile of these households cannot be accurately obtained. This is due to the possibility that in those households where contact could not be achieved, many may have been unoccupied, or the resident population in each household may be lower (assuming that the more people residing in a household, the more likely it is that someone will be home when an interviewer calls).

Our estimates suggest, however, that reasonably good response rates were obtained from those households where contact could be achieved. Furthermore, considering the duration and nature of the testing procedures involved in the biomedical examination for each individual, the response to the biomedical examination is acceptable. Nevertheless, additional in-depth analyses will be necessary to explore whether specific non-response biases exist at both the national and state level.

Regarding the analysis of non-response bias presented, there are several points worth noting. Firstly, the difference in the percentage of English speakers between responders and non-responders shown in Table 4, while being significant, was fairly small (96.1 vs. 93.6%) and is unlikely to have had a significant impact on diabetes or other prevalence estimates. Similarly, the percentage of responders born in the UK was only slightly greater than the percentage of non-responders born in the UK (10.3 vs. 8.8%), although again, this difference was significant. Most of the difference in country of birth between responders and non-responders was removed by age and gender-standardisation. It is unlikely that the percentage of people born in the UK would have an important effect on diabetes prevalence estimates, since many cultural similarities exist for those born in the UK and those born in Australia.

The greatest differences between responders and non-responders were observed in suspicion of diabetes and level of education. Firstly, the percentage of those who suspected they had diabetes (but have never been told they do) was significantly higher in the responders (1.5%) compared to the non-responders (0.5%). Only one in 12 of those who suspected they had diabetes were actually found to have the disease, compared to one in 25 of those who did not suspect they had diabetes. Taking into account the very low prevalence of those who suspected they had diabetes, and the low prevalence of those found to actually have diabetes when they suspected they had diabetes, the difference between responders and non-responders with respect to suspicion of diabetes would have increased the total number of newly diagnosed cases of diabetes by 6 or 7 persons at most. This would be expected to have only a negligible effect on the total prevalence estimates for diabetes.

Participants who attended the biomedical examination were more likely to have completed the final year of high school, University or other higher education (58.2 vs. 51.3%) than non-responders. This would indicate that the higher socio-economic groups were over-represented in AusDiab. This difference could potentially bias estimates of diabetes, as well as other studied variables. However, for glucose intolerance, as well as other cardiovascular disease risk factors such as dyslipidaemia, physical activity, alcohol consumption and smoking, there is a negative association with socio-economic status [10]. Therefore, our estimates of these disease states, if a socio-economic bias does indeed exist, are likely to underestimate the true prevalence. Of course, education level is only one indicator of socio-economic status, and other variables such as income level, occupation and type of residence will need to be considered in further analyses of response bias. Detailed comparisons between responders and the Australian population aged over 25 (using both census data and other previous surveys), particularly in the areas of socio-economic status, language spoken and suspicion of diabetes, will be valuable in assessing more precisely the impact of any response bias in the AusDiab survey.

AusDiab is a major achievement in the study of diabetes in Australia. The study not only provides much needed data on the current magnitude of the diabetes epidemic that exists in Australia but also fills a 10-year void in knowledge on current levels of many of the associated cardiovascular disease risk factors that can only be determined through blood collection. Furthermore, an important extension to this initiative will be the follow-up of the AusDiab cohort, that will provide the first opportunity ever in Australia to examine the natural history of diabetes and its complications, as well as the incidence of cardiovascular disease among this representative sample of Australians with diabetes or impaired glucose metabolism.

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