Family Practice, 2024, **41**, 680–692
https://doi.org/10.1093/fampra/cmae015
Advance access publication 13 March 2024
Epidemiology

Identifying risk factors for developing obesity: a record linkage longitudinal study in metropolitan Sydney using the 45 and Up Study

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Background: Primary care clinicians have key responsibilities in obesity prevention and weight management.

Aims: We aimed to identify risk factors for developing obesity among people aged ≥45 years.

Methods: We conducted a record linkage longitudinal study of residents of metropolitan Sydney, Australia using data from the: (1) 45 and Up Study at baseline (2005–2009) and first follow-up (2012–2015); (2) Medicare claims; (3) Pharmaceutical Benefits Scheme; and (4) deaths registry. We examined risk factors for developing obesity (body mass index [BMI]: 30–40) at follow-up, separately for people within the: (1) healthy weight range (BMI 18.5–<25) and (2) overweight range (BMI 25–<30) at baseline. Covariates included demographics, modifiable behaviours, health status, allied health use, and medication use. Crude and adjusted relative risks were estimated using Poisson regression modelling.

Results: At follow-up, 1.1% (180/16,205) of those in the healthy weight range group, and 12.7% (1,939/15,266) of those in the overweight range group developed obesity. In both groups, the following were associated with developing obesity: current smoking at baseline, physical functioning limitations, and allied health service use through team care planning, while any alcohol consumption and adequate physical activity were found to be associated with a lower risk of developing obesity. In the healthy weight group, high psychological distress and the use of antiepileptics were associated with developing obesity. In the overweight group, female sex and full-time work were associated with developing obesity, while older age was found to be associated with a lower risk of developing obesity.

Conclusions: These findings may inform the targeting of preventive interventions for obesity in clinical practice and broader public health programs.

Lay summary

Early intervention to prevent weight gain requires a targeted multidisciplinary team-based approach to improve diet, increase physical activity, and change behaviour. However, the capacity to provide this within primary care is limited and there is little funding for consultations with allied health professionals. There is a need to identify priority at-risk groups to help primary care clinicians target interventions to those in most need. We have identified, using a longitudinal study of residents of metropolitan Sydney, key characteristics of older adults who are at risk of gaining weight and developing obesity, including risk behaviours (smoking and physical inactivity), and chronic conditions or their treatment (physical function, psychological distress, and use of anti-epileptic medications). These findings may help alert clinicians to the need for preventive interventions in selected cases, as well as informing the targeting of public health programs.

Key words: general practice, obesity, preventive care, risk factors

Background

The World Health Organisation estimated obesity (Body mass index [BMI]; ≥30) increased 3-fold globally between 1975 and 2016.[1] Obesity is the greatest contributing factor to the chronic disease burden, and is associated with higher healthcare utilisation and mortality.[2–4] A meta-analysis of 28 international studies found obesity is associated with a 36% median healthcare cost increase compared to healthy weight.[5] Australia has one of the world's highest rates of adult obesity; there were 31% of Australians with obesity in 2017–2018, and the prevalence is rising.[6] If this trend continues, the Australian Bureau of Statistics predicts there will be 18 million Australians with obesity or overweight by 2030.[7]

Primary care clinicians, with their focus on longitudinal comprehensive person-centred care, have important responsibilities in obesity prevention and weight management.[8] The Australian Government, through the Medicare universal health insurance scheme, provides rebates for general practice consultations and team care arrangements.[9] Most

Key messages

- A targeted multidisciplinary approach is required for obesity prevention.
- Identifying priority at-risk groups will help to target interventions.
- Smoking and physical inactivity are associated with developing obesity.
- Chronic conditions or their treatment are also associated with developing obesity.

general practitioners (GPs) work together in small (2–5 doctors) group practices that are privately-owned, with 76% of GPs working with other healthcare professionals within the same practice.[10,11] The majority of Australians (85%; 21 million approximately) will see their GP at least once per year[10]; and 90% of these presentations are managed entirely within primary care. Patients prefer to receive weight management support from their GP rather than other healthcare professionals.[12] Early intervention requires a targeted multidisciplinary approach to improve diet, increase physical activity, and change behaviour.[13] However, capacity to provide this within primary care is limited and Medicare currently funds only 5 consultations with allied health professionals each year.[9] There is a need to identify priority at-risk groups to help target such interventions to those in most need.[14]

Further research is required to assist primary care clinicians to identify people at risk of developing obesity for targeting prevention interventions.[15] However, most epidemiological studies assessing this have been based on cross-sectional designs.[16,17] We aimed to identify risk factors for developing obesity among people aged ≥45 years for those in the healthy and overweight weight range over a 5–7-year period with a focus on the role of primary care.

Methods

Design, setting, and participants

We conducted a prospective population-based cohort study of people aged ≥ 45 years residing in Sydney metropolitan area using the Central and Eastern Sydney Primary and Community Health Cohort (CES-P&CH)[18] derived from the Sax Institute's 45 and Up Study.[19] The 45 and Up Study collected information from 267,357 people living in New South Wales (NSW) between 2005 and 2009. Prospective study participants aged ≥ 45 years and living in NSW were randomly sampled from the Services Australia Medicare enrolment database, with oversampling of people aged 80 years and over, and those living in rural and remote areas. About 19% of those invited joined the study (participants included ≈ 11% of the NSW population aged ≥ 45 years) by completing the baseline questionnaire and providing consent for long-term follow-up, including linkage of their questionnaire data to routinely collected records. Participants living in metropolitan Sydney who completed both the baseline and first follow-up questionnaires (2012–2015) with BMIs between 18.5 and < 30 at baseline were included in this analysis. We divided our analytic cohort into 2 groups to assess any variation in factors associated with developing obesity (BMI [calculated as weight in kilograms divided by height in metres squared] ≥ 30) among those within the: (1) healthy weight range (BMI 18.5 to <25.0) and (2) overweight range (BMI 25.0 to <30.0) at baseline. Participants with a self-reported BMI of >40 were excluded because management usually does not occur in primary care alone.

Data linkage

The Sax Institute facilitated linkage of the 45 and Up Study questionnaire data with Medicare claims and Pharmaceutical Benefits Scheme (PBS) data provided by Services Australia using a unique identifier and deterministic matching. The NSW Centre for Health Record Linkage (CHeReL) linked death notifications from the NSW Registry of Births Deaths and Marriages with the 45 and Up Study questionnaire data using probabilistic matching.

Outcome and covariates

Outcome The study outcome was obesity (BMI ≥ 30) based on self-reported weight and height recorded in the first follow-up questionnaire between 2012 and 2015.

Covariates Table 1 shows participant demographics, health behaviours, and health status at baseline (2005–2009). Primary care usage (including allied health usage as part of chronic care team planning) and medication use were ascertained for each participant during the time period between baseline and follow-up (2012–2015) surveys.

Physical activity was measured using the Australian Physical Activity and Sedentary Behaviour Guidelines.[20] Study participants self-reported their physical activity in the week prior to completion of the baseline questionnaire. This was calculated by adding minutes spent walking continuously for at least 10 minutes, minutes spent on moderate physical activity (e.g. gardening or housework), and minutes spent on vigorous physical activity (e.g. jogging or cycling), where time spent on vigorous exercise only was multiplied by 2 as it is more beneficial. Adequate physical activity was defined as undertaking physical activity for a total of at least 150 minutes per week over 5 separate occasions within that week.[20]

Self-reported quality of life was measured on a 5-point Likert scale (excellent, very good, good, fair, or poor) in the baseline questionnaire. Good quality of life was defined by excellent, very good, or good responses.

Psychological distress was measured using 10 items in the Kessler Psychological Distress Score (K10) in the baseline questionnaire.[22] K10 scores range from 10 to 50. High psychological distress was defined by a score of 22 or greater.

Physical functioning scores were calculated using 10 items of physical functioning in the 36-item short-form (SF-36) tool in the baseline questionnaire.[23] Physical functioning scores range between 0 and 100. Physical function was categorized as: "no limitation" for scores of 100, "minor limitation" for scores of 90 to <100, "moderate limitation" for scores of 60 to <90, and "severe limitation" for scores of 0 to <60.

Self-reported past personal history of chronic health conditions included up to 11 conditions (cancer, heart disease, high

Table 1. Baseline participant characteristics and descriptions.

Characteristic	Question	Categorisation for analysis
Age group	Self-reported age	45–59 years 60–74 years 75 years and over
Sex	Male questionnaire Female questionnaire	Male Female
Highest qualification	Self-reported highest level of educational qualification—categorised as	No school certificate or other qualification School or intermediate certificate Higher school or leaving certificate Trade or apprenticeship Certificate or diploma University degree or higher
Work status	Working status	Not working Working part-time Working full-time
Household income	Self-reported household income category (in Australian dollars [AUD])	<$20,000 $20,000–39,999 $40,000–69,999 $70,000 or more Won't disclose
Born in Australia	In which country where you born?	Yes: born in Australia No: otherwise
Speaks language other than English at home	Whether a language other than English is spoken at home?	Yes: speaks language other than English at home No: speaks only English at home
Currently married/partnered	Current marital status	Yes: currently married/partnered No: not currently married/partnered
Smoking status	Smoking status	Never smoked Ex-smoker Current smoker
Adequate vegetable intake (5 or more serves a day)	How many serves of vegetables do you usually eat each day?	Yes: 5 or more serves No: none or less than 5 serves
Adequate fruit intake (2 or more serves a day)	How many serves of fruit or glass of fruit juice do you usually have each day	Yes: 2 or more serves No: none or less than 2 serves
Alcohol consumption	Based on self-reported number of standard drinks each week-	Yes: 1 or more drinks per week No: zero
Adequate physical activity	Based on amount of self-reported physical activity[20]	Yes: adequate physical activity No: inadequate physical activity
Good quality of life	Self-reported quality of life on a Likert scale	Yes: excellent, very good or good quality of life No: fair or poor quality of life
Chronic conditions	Has a doctor EVER told you that you have: cancer, heart disease, high blood pressure, stroke, diabetes, blood clot, asthma, hay fever, depression, anxiety, or Parkinson's disease	None One Two or more
Psychological distress- Index calculated based on 10 indicators	During the past 4 weeks about how often did you feel: Tired out for no good reason? Nervous? So nervous that nothing could calm you down? Hopeless? Restless or fidgety? So restless that you could not sit still? Depressed? That everything was an effort? So sad that nothing could cheer you up? Worthless?	Responses for each indicator 1 = none of the time 2 = a little of the time 3 = some of the time 4 = most of the time 5 = all the time Low = total score < 22 High = total score >=22
Physical functioning	Based on scores calculated from 10 items of physical functioning in the 36-item short-form (SF-36) tool (23)	No limitation = score of 100 Minor limitation = score of 90 to <100 Moderate limitation = score of 60 to <90 Severe limitation = score of 0 to <60
Needing help with daily activity	Do you regularly need help with daily tasks because of long-term illness or disability	Yes No
Allied health service use through team care arrangement*	If any of the following MBS item numbers were recorded: 10954, 10953, 10962, 10964, and 10960	Yes: any of them recorded No: none of them recorded

Table 1. Continued

Characteristic	Question	Categorisation for analysis
Use of psychotropic medications#	If any of the following ATC codes are recorded: N06AF03 (phenelzine), N06AF04 (tranylcypromine), N06AA09 (amitriptyline), N06AA04 (clomipramine), N06AA16 (dosulepin), N06AA12 (doxepin), N06AA02 (imipramine), N06AA10 (nortriptyline), N06AX11 (mirtazapine), N05AL05 (amisulpride), N05AX12 (aripiprazole), N05AH05 (asenapine), N05AX16 (brexpiprazole), N05AX15 (cariprazine), N05AA01 (chlorpromazine), N05AH02 (clozapine), N05AD08 (droperidol), N05AF01 (flupentixol), N05AD01 (haloperidol), N05AE05 (lurasidone), N05AH03 (olanzapine), N05AX13 (paliperidone), N05AC01 (periciazine), N05AH04 (quetiapine), N05AX08 (risperidone), N05AB06 (trifluoperazine), N05AE04 (ziprasidone), N05AF05 (zuclopenthixol) and N05AN01 (lithium).	Yes: any of them recorded No: none of them recorded
Use of diabetic medications #	If any of the following ATC codes are recorded: A10BB01 (glibenclamide), A10BB09 (gliclazide), A10BB12 (glimepiride), A10BB07 (glipizide), A10AB06 (insulin) and A10BG03 (pioglitazone).	Yes: any of them recorded No: none of them recorded
Use of antiepileptic medications#	If any of the following ATC codes are recorded: N03AX12 (gabapentin), N03AX22 (perampanel), N03AX16 (pregabalin), N03AG01 (valproate) and N03AG04 (vigabatrin).	Yes: any of them recorded No: none of them recorded
Body mass index (BMI)	Calculation based on 2 questions: How tall are you without shoes (in centimetres or feet and inches)? How much do you weigh (in kilograms or stones and pounds)?	Underweight: <18.5 Normal weight: 18.5–24.9 Overweight: 25.0–29.9 Obesity: ≥30

Data was sourced from the 45 and Up Study at baseline questionnaire (2005–2009),[21] except for *allied healthcare use which was sourced from Medicare claims data and #medication use which was sourced from Pharmaceutical Benefits Scheme data between baseline and follow-up surveys (2005–2011; prior to change in weight).

blood pressure, stroke, diabetes, blood clot, asthma, hay fever, depression, anxiety, or Parkinson's disease) self-reported in the baseline questionnaire.

Allied health usage as part of chronic care team planning was ascertained from Medicare claims data, which contains date of the consultations, Medicare Benefits Schedule (MBS) item numbers, provider charge, and benefit paid for the service. Allied health usage included consultations with dieticians, exercise physiologists, podiatrists, chiropractors and physiotherapists (MBS item numbers 10954, 10953, 10962, 10964, and 10960 respectively).[9] If any of these 5 item numbers were recorded in Medicare claims data at any time between baseline and first follow-up questionnaire, then the person was considered as using allied health services through chronic care team planning.

Use of psychotrophic, diabetic, and antiepileptic medications associated with weight gain[24] as provided in Table 1 were ascertained from the PBS data, which consists of Anatomical Therapeutic Chemical (ATC) classification of drugs, date of supply and prescription, net benefit, and patient's contribution. If any of these ATC codes were recorded in PBS data at any time between baseline and first follow-up questionnaire, then the person was considered as using these medications.

Statistical analyses

We created 3 age categories (45–59 years, 60–74 years, and ≥75 years) to assess any differential effect of age on the risk of developing obesity. We calculated values for health status variables (e.g. BMI and psychological distress[22]). Missing data were excluded; except where tool calculation allows substitution of averages (e.g. psychological distress[22]). We calculated frequencies and proportions for participant characteristics and the cumulative incidence of obesity at the first follow-up questionnaire by each category of covariates. Relative risk (RR) was used to estimate the association of baseline characteristics, the use of allied health services, and different types of medication with obesity at follow-up. We used simple and multiple Poisson regression models to estimate crude and adjusted RRs and their 95% confidence intervals (CIs). In the multiple Poisson model, we included all the variables in Table 1. We set $P = 0.05$ as a cut-off for all statistical significance. A variance inflation factor (VIF) was used to check for multicollinearity with the cut-off set at greater than 10. We used R 4.1.3 software (R Foundation, Vienna, Austria) for data analysis and SAS 9.4 (SAS Institute, Cary, NC) for data management. We used "glm" command with Poisson family and log link function to fit the Poisson model and used "vif" command from "car" package in R.

Results

There were 31,471 participants with BMIs between 18.5 and < 30.0 at baseline who were alive up until the follow-up survey and completed both the baseline and follow-up questionnaires (Figure 1). The healthy weight group (BMI 18.5 to <25.0 at baseline) comprised 16,205 participants, and the overweight group (BMI 25.0 to <30.0 at baseline) comprised 15,266 participants; and the mean follow-up time for both groups was 6.3 years. At follow-up, incidence of obesity was

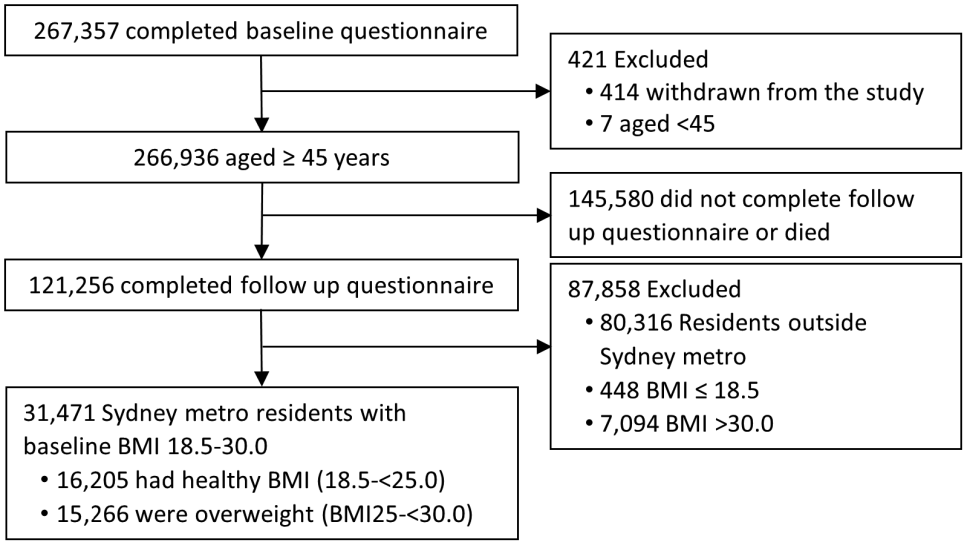

Figure 1. Assembly of the analytic cohort. This diagram summarises the assembly of the analytic cohort.

1.1% (180/16,205) in the healthy weight group and 12.7% (1,939/15,266) in the overweight group.

Factors associated with developing obesity in the healthy weight group (BMI 18.5 to <25.0)

Table 2 shows the cumulative incidence of obesity at follow-up among people within the healthy weight range at baseline, with crude and adjusted RRs by covariate categories. While obesity incidence was slightly higher among older age groups, adjusted analysis did not show any significant association between age group and developing obesity. We did not find any statistically significant associations between other socio-demographic variables and developing obesity at follow-up.

Current smokers at baseline were at higher risk of developing obesity compared to those who had never smoked (adjusted RR: 2.96; 95%CI: 1.73–4.81), while any alcohol consumption (adjusted RR: 0.59; 95%CI: 0.41–0.85) and adequate physical activity (adjusted RR: 0.44; 95%CI: 0.31–0.63) were found to be associated with a lower risk of developing obesity. People reporting high levels of psychological distress were at higher risk of developing obesity compared with those reporting no or low level of psychological distress (adjusted RR: 2.01; 95%CI: 1.13–3.38). People reporting severe physical functional limitations were at higher risk of developing obesity compared to those with none (adjusted RR: 2.93; 95%CI: 1.50–5.45). People who used allied health services through team care planning were 62% more likely to develop obesity compared to people who did not (adjusted RR: 1.62, 95%CI: 1.06–2.42). People who used antiepileptics were 2.08-fold more likely to develop obesity (adjusted RR: 2.08; 95%CI: 1.03–3.86) compared with people who did not, while the use of psychotropic and diabetic medications had no significant effect (adjusted RR: 1.46; 95%CI: 0.92–2.26 and adjusted RR 1.38; 95%CI: 0.47–3.20, respectively). There was no multicollinearity demonstrated among covariates in the multivariable Poisson model; the VIFs for all covariates were <1.20 (data not shown).

Factors associated with developing obesity in the overweight group (BMI 25.0 to <30.0)

Table 3 shows the cumulative incidence of obesity at follow-up among people who were overweight at baseline, with crude and adjusted RRs by covariate categories. The risk of developing obesity at follow-up significantly decreased with increasing age. Compared to people aged 45–59 years, the risk of developing obesity was 17% less for those aged 60–74 years (adjusted RR: 0.83, 95%CI: 0.73–0.94) and 56% less for those aged ≥75 years (adjusted RR: 0.44, 95%CI: 0.34–0.56), respectively. Females were 34% more likely to develop obesity compared with males (adjusted RR: 1.34; 95%CI: 1.20–1.50). Full-time workers were 26% more likely to develop obesity compared to those who did not work (adjusted RR: 1.26; 95%CI: 1.08–1.47).

Current smokers at baseline were at higher risk of developing obesity compared to those who had never smoked (adjusted RR: 1.47; 95%CI: 1.20–1.79), while any alcohol consumption (adjusted RR: 0.81; 95%CI: 0.72–0.90) and adequate physical activity (adjusted RR: 0.88; 95%CI: 0.79–0.99) were found to be associated with a lower risk of developing obesity. People reporting physical functional limitations were at higher risk of developing obesity: for people reporting minor limitations compared to none (adjusted RR: 1.12; 95%CI: 1.18–1.27), for people reporting moderate limitations compared to none (adjusted RR: 1.36; 95%CI: 1.18–1.56), and for people reporting severe limitations compared to none (adjusted RR: 1.50; 95%CI: 1.19–1.88). People who had 2 or more chronic conditions were 14% more likely to develop obesity compared to those with none (adjusted RR: 1.14; 95%CI: 1.00–1.30) and those who used allied health services during follow-up time through team care planning were 28% more like to develop obesity compared to those who did not use these services (adjusted RR: 1.28; 95%CI: 1.13–1.44). We did not find any significant association between different types of medication use during follow-up and obesity. There was no multicollinearity observed among covariates in the multivariable Poisson model; the VIFs for all covariates were <1.20.

Discussion

This population-based community-dwelling cohort study has identified risk factors for developing obesity in people of healthy weight and those who are overweight. Transition to

Table 2. Risk factors for obesity at follow-up among people in the healthy weight range (BMI 18.5 to <25)

Characteristics	Number	Without obesity *n* (%)	Obesity *n* (%)	Crude relative risk (95% confidence interval)	Adjusted* relative risk (95% confidence interval)	*P*-value
Age at baseline						
45–59 years	9,098	9,000 (98.9)	98 (1.1)	1	1	
60–74 years	5,269	5,211 (98.9)	58 (1.1)	1.02 (0.73, 1.41)	0.83 (0.52, 1.29)	0.412
75 years and over	1,838	1,814 (98.7)	24 (1.3)	1.21 (0.76, 1.86)	0.63 (0.30, 1.28)	0.215
Sex						
Male	6,254	6,188 (98.9)	66 (1.1)	1	1	
Female	9,951	9,837 (98.9)	114 (1.1)	1.09 (0.80, 1.48)	0.82 (0.56, 1.21)	0.317
Highest qualification						
No school certificate or other qualification	599	585 (97.7)	14 (2.3)	1	1	
School or intermediate certificate	2,173	2142 (98.6)	31 (1.4)	0.61 (0.33, 1.18)	0.99 (0.49, 2.19)	0.987
Higher school or leaving certificate	1,611	1,586 (98.4)	25 (1.6)	0.66 (0.35, 1.31)	1.17 (0.55, 2.68)	0.689
Trade or apprenticeship	947	939 (99.2)	8 (0.8)	0.36 (0.14, 0.84)	0.53 (0.18, 1.46)	0.226
Certificate or diploma	3,625	3,586 (98.9)	39 (1.1)	0.46 (0.26, 0.88)	0.85 (0.42, 1.87)	0.665
University degree or higher	7,132	7,072 (99.2)	60 (0.8)	0.36 (0.21, 0.67)	0.65 (0.32, 1.43)	0.251
Work status						
Not working	5,750	5,678 (98.7)	72 (1.3)	1	1	
Part time	4,219	4,182 (99.1)	37 (0.9)	0.70 (0.47, 1.03)	1.10 (0.66, 1.84)	0.713
Full time	5,972	5,904 (98.9)	68 (1.1)	0.91 (0.65, 1.27)	1.22 (0.72, 2.10)	0.460
Household income (AUD)						
<$20,000	1,415	1,391 (98.3)	24 (1.7)	1	1	
$20,000–39,999	1,923	1,899 (98.8)	24 (1.2)	0.74 (0.42, 1.30)	1.03 (0.51, 2.03)	0.969
$40,000-69,999	3,064	3034 (99.0)	30 (1.0)	0.58 (0.34, 1.00)	0.93 (0.47, 1.86)	0.825
$70,000 or more	6,887	6827 (99.1)	60 (0.9)	0.51 (0.32, 0.84)	1.12 (0.56, 2.30)	0.754
Won't disclose	2,916	2,874 (98.6)	42 (1.4)	0.85 (0.52, 1.42)	1.20 (0.63, 2.34)	0.583
Born in Australia						
No	5,452	5,404 (99.1)	48 (0.9)	1	1	
Yes	10,674	10,544 (98.8)	130 (1.2)	1.38 (1.00, 1.94)	1.50 (0.98, 2.34)	0.069
Speaks language other than English at home						
No	14,100	13,944 (98.9)	156 (1.1)	1	1	
Yes	2,105	2,081 (98.9)	24 (1.1)	1.03 (0.65, 1.55)	1.02 (0.56, 1.78)	0.945
Currently married/partnered						
No	3,798	3,745 (98.6)	53 (1.4)	1	1	
Yes	12,348	12,224 (99.0)	124 (1.0)	0.72 (0.52, 1.00)	0.85 (0.57, 1.28)	0.434
Smoking status						
Never smoker	10,674	10,566 (99.0)	108 (1.0)	1	1	
Ex-smoker	4,758	4,712 (99.0)	46 (1.0)	0.96 (0.67, 1.34)	1.12 (0.74, 1.65)	0.585
Current smoker	773	747 (96.6)	26 (3.4)	3.32 (2.12, 5.02)	2.96 (1.73, 4.81)	<0.001
Adequate vegetable intake (5 or more serves a day)						
No	11,739	11,614 (98.9)	125 (1.1)	1	1	
Yes	4,466	4411 (98.8)	55 (1.2)	1.16 (0.84, 1.58)	1.20 (0.82, 1.74)	0.331
Adequate fruit intake (2 or more serves a day)						
No	6,008	5,940 (98.9)	68 (1.1)	1	1	
Yes	10,197	10,085 (98.9)	112 (1.1)	0.97 (0.72, 1.32)	1.06 (0.74, 1.52)	0.763
Alcohol consumption						
No	4,175	4,105 (98.3)	70 (1.7)	1	1	
Yes	11,866	11,757 (99.1)	109 (0.9)	0.55 (0.41, 0.74)	0.59 (0.41, 0.85)	0.005

Table 2. Continued

Characteristics	Number	Without obesity *n* (%)	Obesity *n* (%)	Crude relative risk (95% confidence interval)	Adjusted* relative risk (95% confidence interval)	*P*-value
Adequate physical activity[a]						
No	3,424	3,351 (97.9)	73 (2.1)	1	1	
Yes	12,781	12,674 (99.2)	107 (0.8)	0.39 (0.29, 0.53)	0.44 (0.31, 0.63)	<0.001
Self-reported good quality of life[b]						
No	710	696 (98.0)	14 (2.0)	1	1	
Yes	14,940	14,778 (98.9)	162 (1.1)	0.55 (0.33, 0.99)	1.69 (0.85, 3.68)	0.157
Number of self-reported chronic conditions						
None	6,189	6,135 (99.1)	54 (0.9)	1	1	
One	5,809	5,738 (98.8)	71 (1.2)	1.40 (0.99, 2.00)	1.13 (0.76, 1.69)	0.545
Two or more	4,207	4,152 (98.7)	55 (1.3)	1.50 (1.03, 2.18)	0.77 (0.47, 1.24)	0.283
Psychological distress[c]						
Low	14,527	14,381 (99.0)	146 (1.0)	1	1	
High	786	764 (97.2)	22 (2.8)	2.78 (1.73, 4.26)	2.01 (1.13, 3.38)	0.013
Physical functioning[d]						
No limitations	7,483	7,419 (99.1)	64 (0.9)	1	1	
Minor limitations	4,454	4,412 (99.1)	42 (0.9)	1.10 (0.74, 1.62)	0.92 (0.59, 1.41)	0.691
Moderate limitations	2,422	2,386 (98.5)	36 (1.5)	1.74 (1.14, 2.60)	1.35 (0.82, 2.16)	0.227
Severe limitations	661	639 (96.7)	22 (3.3)	3.89 (2.35, 6.21)	2.93 (1.50, 5.45)	0.001
Needing help with daily activity						
No	15,460	15,291 (98.9)	169 (1.1)	1	1	
Yes	253	248 (98.0)	5 (2.0)	1.81 (0.64, 3.95)	0.56 (0.18, 1.40)	0.254
Allied health service use through team care arrangements[e]						
No	13,467	13,341 (99.1)	126 (0.9)	1	1	
Yes	2,738	2,684 (98.0)	54 (2.0)	2.11 (1.52, 2.88)	1.62 (1.06, 2.42)	0.021
Use of psychotropic medications[f]						
No	14,145	14,005 (99.0)	140 (1.0)	1	1	
Yes	2,060	2,020 (98.1)	40 (1.9)	1.96 (1.36, 2.76)	1.46 (0.92, 2.26)	0.095
Use of diabetic medications[g]						
No	15,894	15,720 (98.9)	174 (1.1)	1	1	
Yes	311	305 (98.1)	6 (1.9)	1.76 (0.69, 3.63)	1.38 (0.47, 3.20)	0.502
Use of antiepileptics[h]						
No	15,834	15,668 (99.0)	166 (1.0)	1	1	
Yes	371	357 (96.2)	14 (3.8)	3.60 (1.99, 5.98)	2.08 (1.03, 3.86)	0.029

*Relative risks were adjusted for all other variables in the table.
[a]Adequate physical activity was defined as at least 150 minutes of activity (walking, or moderate and vigorous exercise) in the week prior to the completion of the baseline survey.
[b]Self-reported good quality of life was defined if people reported their quality of life was good, very good or excellent in response to the self-rated quality of life question.
[c]Psychological distress was measured using the Kessler Psychological Distress Scale (K10)[22] and categorised as either low and moderate (<22) or high (>22) based on the K10 score that ranges between 10 and 50.
[d]Physical functioning score was measured using the RAND Health Medical Outcomes Study Physical Functioning (MOS-PF) scale[23] and was classified as no limitations (≥81), minor limitations (61–81), moderate limitations (41–60), or severe limitations (≤40).
[e]Services delivered by accredited dieticians, exercise physiologists, podiatrists, chiropractors, and physiotherapists through team care arrangements.
[f]Psychotrophic medications included: antidepressants (phenelzine, tranylcypromine, amitriptyline, clomipramine, dosulepin, doxepin, imipramine, nortriptyline, mirtazapine), antipsychotics (amisulpride, aripiprazole, asenapine, brexpiprazole, cariprazine, chlorpromazine, clozapine, droperidol, flupentixol, haloperidol, lurasidone, olanzapine, paliperidone, periciazine, quetiapine, risperidone, trifluoperazine, ziprasidone, and zuclopenthixol), and drugs for bipolar disorder (lithium).
[g]Antiepileptics included: gabapentin, perampanel, pregabalin, valproate, and vigabatrin.
[h]Diabetic medications included: sulfonylureas (glibenclamide, gliclazide, glimepiride, glipizide) and other drugs for diabetes (insulin and pioglitazone).

obesity was common in this cohort. We have identified characteristics associated with that transition which can be used by primary care clinicians to identify those most at risk so they can be offered interventions to support obesity prevention and weight management in primary care. In this study, 1.1% of people within the healthy weight range experienced

Table 3. Risk factors for obesity at follow-up among people in the overweight range (BMI 25-<30)

Characteristics	Number	Without obesity *n* (%)	Obesity *n* (%)	Crude relative risk (95% confidence interval)	Adjusted* relative risk (95% confidence interval)	*P*-value
Age at baseline						
45–59 years	7,913	6,816 (86.1)	1097 (13.9)	1	1	
60–74 years	5,769	5,053 (87.6)	716 (12.4)	0.90 (0.81, 0.98)	0.83 (0.73, 0.94)	0.005
75 years and over	1,584	1,458 (92.0)	126 (8.0)	0.57 (0.47, 0.69)	0.44 (0.34, 0.56)	<0.001
Sex						
Male	8,878	7,922 (89.2)	956 (10.8)	1	1	
Female	6,388	5,405 (84.6)	983 (15.4)	1.43 (1.31, 1.56)	1.34 (1.20, 1.50)	<0.001
Highest qualification						
No school certificate or other qualification	727	618 (85.0)	109 (15.0)	1	1	
School or intermediate certificate	2,252	1919 (85.2)	333 (14.8)	0.99 (0.80, 1.23)	1.06 (0.83, 1.38)	0.651
Higher school or leaving certificate	1,543	1,327 (86.0)	216 (14.0)	0.93 (0.74, 1.18)	1.04 (0.79, 1.37)	0.784
Trade or apprenticeship	1,336	1139 (85.3)	197 (14.7)	0.98 (0.78, 1.25)	1.13 (0.86, 1.50)	0.384
Certificate or diploma	3,350	2,897 (86.5)	453 (13.5)	0.90 (0.73, 1.12)	0.99 (0.78, 1.28)	0.951
University degree or higher	5,936	5,323 (89.7)	613 (10.3)	0.69 (0.56, 0.85)	0.81 (0.63, 1.05)	0.104
Work status						
Not working	5,465	4,823 (88.3)	642 (11.7)	1	1	
Part time	3,243	2,827 (87.2)	416 (12.8)	1.09 (0.96, 1.23)	1.09 (0.94, 1.27)	0.259
Full time	6,400	5,541 (86.6)	859 (13.4)	1.14 (1.03, 1.27)	1.26 (1.08, 1.47)	0.004
Household income (AUD)						
<$20,000	1,415	1,212 (85.7)	203 (14.3)	1	1	
$20,000–39,999	1,833	1,579 (86.1)	254 (13.9)	0.97 (0.80, 1.16)	1.03 (0.83, 1.28)	0.783
$40,000–69,999	2,858	2,446 (85.6)	412 (14.4)	1.00 (0.85, 1.19)	1.03 (0.84, 1.28)	0.764
$70,000 or more	6,599	5,859 (88.8)	740 (11.2)	0.78 (0.67, 0.92)	0.90 (0.72, 1.13)	0.374
Won't disclose	2,561	2,231 (87.1)	330 (12.9)	0.90 (0.75, 1.07)	0.94 (0.76, 1.17)	0.574
Born in Australia						
No	4,489	3,952 (88.0)	537 (12.0)	1	1	
Yes	10,694	9,305 (87.0)	1389 (13.0)	1.09 (0.98, 1.20)	1.10 (0.97, 1.24)	0.137
Speaks language other than English at home						
No	13,617	11,889 (87.3)	1728 (12.7)	1	1	
Yes	1,649	1,438 (87.2)	211 (12.8)	1.01 (0.87, 1.16)	0.98 (0.82, 1.17)	0.835
Currently married/partnered						
No	3,010	2,537 (84.3)	473 (15.7)	1	1	
Yes	12,171	10,711 (88.0)	1460 (12.0)	0.76 (0.69, 0.85)	0.90 (0.80, 1.02)	0.103
Smoking status						
Never smoker	9,084	8,006 (88.1)	1078 (11.9)	1	1	
Ex-smoker	5,524	4,796 (86.8)	728 (13.2)	1.11 (1.01, 1.22)	1.09 (0.98, 1.21)	0.132
Current smoker	658	525 (79.8)	133 (20.2)	1.70 (1.42, 2.03)	1.47 (1.20, 1.79)	<0.001
Adequate vegetable intake (5 or more serves a day)						
No	11,292	9,889 (87.6)	1403 (12.4)	1	1	
Yes	3,974	3,438 (86.5)	536 (13.5)	1.09 (0.98, 1.20)	1.01 (0.90, 1.13)	0.879
Adequate fruit intake (2 or more serves a day)						
No	6,398	5,581 (87.2)	817 (12.8)	1	1	
Yes	8,868	7,746 (87.3)	1122 (12.7)	0.99 (0.91, 1.08)	0.99 (0.89, 1.10)	0.807
Alcohol consumption						
No	3,568	2,998 (84.0)	570 (16.0)	1	1	
Yes	11,539	10,190 (88.3)	1349 (11.7)	0.73 (0.66, 0.81)	0.81 (0.72, 0.90)	<0.001

Table 3. Continued

Characteristics	Number	Without obesity *n* (%)	Obesity *n* (%)	Crude relative risk (95% confidence interval)	Adjusted* relative risk (95% confidence interval)	*P*-value
Adequate physical activity[a]						
No	3,959	3,375 (85.2)	584 (14.8)	1	1	
Yes	11,307	9,952 (88.0)	1355 (12.0)	0.81 (0.74, 0.90)	0.88 (0.79, 0.99)	0.026
Self-reported good quality of life[b]						
No	737	606 (82.2)	131 (17.8)	1	1	
Yes	14,016	12,275 (87.6)	1741 (12.4)	0.70 (0.59, 0.84)	1.09 (0.87, 1.39)	0.465
Number of self-reported chronic conditions						
None	4,753	4,183 (88.0)	570 (12.0)	1	1	
One	5,498	4,842 (88.1)	656 (11.9)	0.99 (0.89, 1.11)	1.01 (0.89, 1.14)	0.876
Two or more	5,015	4,302 (85.8)	713 (14.2)	1.19 (1.06, 1.32)	1.14 (1.00, 1.30)	0.054
Psychological distress[c]						
Low	13,705	12,009 (87.6)	1,696 (12.4)	1	1	
High	799	649 (81.2)	150 (18.8)	1.52 (1.28, 1.79)	1.18 (0.97, 1.44)	0.095
Physical functioning[d]						
No limitations	5,611	5,003 (89.2)	608 (10.8)	1	1	
Minor limitations	4,782	4,206 (88.0)	576 (12.0)	1.11 (0.99, 1.25)	1.12 (1.00, 1.27)	0.060
Moderate limitations	2,853	2,413 (84.6)	440 (15.4)	1.42 (1.26, 1.61)	1.36 (1.18, 1.56)	<0.001
Severe limitations	869	708 (81.5)	161 (18.5)	1.71 (1.43, 2.03)	1.50 (1.19, 1.88)	0.001
Needing help with daily activity						
No	14,548	12,712 (87.4)	1,836 (12.6)	1	1	
Yes	248	201 (81.0)	47 (19.0)	1.50 (1.11, 1.98)	1.11 (0.77, 1.57)	0.559
Allied health service use through team care arrangements[e]						
No	11,944	10,554 (88.4)	1,390 (11.6)	1	1	
Yes	3,322	2,773 (83.5)	549 (16.5)	1.42 (1.29, 1.57)	1.28 (1.13, 1.44)	<0.001
Use of psychotropic medications [f]						
No	13,215	11,582 (87.6)	1,633 (12.4)	1	1	
Yes	2,051	1,745 (85.1)	306 (14.9)	1.21 (1.07, 1.36)	1.02 (0.88, 1.18)	0.779
Use of diabetic medications[g]						
No	14,630	12,801 (87.5)	1,829 (12.5)	1	1	
Yes	636	526 (82.7)	110 (17.3)	1.38 (1.13, 1.67)	1.23 (0.97, 1.54)	0.070
Use of antiepileptic medications[h]						
No	14,850	12,985 (87.4)	1,865 (12.6)	1	1	
Yes	416	342 (82.2)	74 (17.8)	1.42 (1.11, 1.77)	1.07 (0.80, 1.40)	0.625

*Relative risks were adjusted for all other variables in the table.
[a]Adequate physical activity was defined as at least 150 minutes of activity (walking, or moderate and vigorous exercise) in the week prior to the completion of the baseline survey.
[b]Self-reported good quality of life was defined if people reported their quality of life was good, very good or excellent in response to the self-rated quality of life question.
[c]Psychological distress was measured using the Kessler Psychological Distress Scale (K10)[22] and categorised as either low and moderate (<22) or high (>22) based on the K10 score that ranges between 10 and 50.
[d]Physical functioning score was measured using the RAND Health Medical Outcomes Study Physical Functioning (MOS-PF) scale[23] and was classified as no limitations (≥81), minor limitations (61–81), moderate limitations (41–60), or severe limitations (≤40).
[e]Services delivered by accredited dieticians, exercise physiologists, podiatrists, chiropractors and physiotherapists through team care arrangements.
[f]Psychotrophic medications included: antidepressants (phenelzine, tranylcypromine, amitriptyline, clomipramine, dosulepin, doxepin, imipramine, nortriptyline, mirtazapine), antipsychotics (amisulpride, aripiprazole, asenapine, brexpiprazole, cariprazine, chlorpromazine, clozapine, droperidol, flupentixol, haloperidol, lurasidone, olanzapine, paliperidone, periciazine, quetiapine, risperidone, trifluoperazine, ziprasidone and zuclopenthixol) and drugs for bipolar disorder (lithium).
[g]Diabetic medications included: sulfonylureas (glibenclamide, gliclazide, glimepiride, glipizide) and other drugs for diabetes (insulin and pioglitazone).
[h]Antiepileptics included: gabapentin, perampanel, pregabalin, valproate, and vigabatrin.

weight gain to develop obesity at follow-up; while 12.7% of people within the overweight range experienced weight gain to develop obesity at follow-up. In both groups, the following were associated with an increased risk of developing obesity: current smoking, physical functioning limitations, and allied health service use through team care planning, while any alcohol consumption and adequate physical activity were found to be associated with a lower risk of developing obesity. Additionally, in the healthy weight group, high psychological distress and the use of antiepileptics were associated with developing obesity; and in the overweight group, being female sex, working full-time, and self-report of 2 or more chronic conditions were associated with developing obesity, while older age was found to be associated with a lower risk of developing obesity.

Our study was different from published cross-sectional epidemiological studies because we were able to use a community-dwelling cohort to explore associations between developing obesity and an extended range of covariates relevant to primary care; including diet, smoking, alcohol consumption, physical activity, physical functioning, self-reported quality of life, psychological distress, allied health use in primary care, and use of 3 classes of medications. A longitudinal cohort study using electronic health records from primary care practices in England found a lower risk of developing obesity with increasing age in people who were a healthy weight and overweight range at baseline,[25] while we found a lower risk of developing obesity with increasing age among people who were overweight at baseline only. The English study included people aged from 18 to 74 years,[25] while ours included an older population who are more likely to be experiencing physical functioning limitations as well as age-related physiological changes such as sarcopenia.[26] Unlike ours, the English study did not include smoking status, allied health use, or medication use (except for diuretics) in their analyses.[25] There is growing evidence that low to moderate alcohol consumption is associated with health benefits as people age; however, it is unclear if this is related to its social benefits or ethanol.[27]

The association between smoking and obesity is complex. The belief that smoking is an effective way to manage body weight and frequent weight gain following smoking cessation is underpinned by the acute energy expenditure and appetite reductions associated with nicotine.[28–30] However, smoking is associated with central obesity and insulin resistance,[31] as well as other poor health habits, such as poor diet and physical inactivity,[32] leading to weight gain and obesity. Our finding that smoking was associated with the transition to obesity builds on the evidence of harms associated with smoking and counteracts the perception some people may have that smoking assists with weight management. GPs have skills and training that enable them to assist their patients with behaviour change regarding smoking and alcohol use, and these skills can also be applied in weight management and obesity care.[33] The risk factors we have identified that could be potentially modifiable after GP and allied health intervention include smoking, physical functioning, physical activity, psychological distress, and use of specific medications. GPs have a central role to play in obesity prevention and management as patients prefer to receive that from GPs rather than other healthcare professionals,[12] and GPs can provide personalised patient-centred care encompassing the condition being treated, other co-morbidities and the personal circumstances of each patient.[33] While we have not differentiated between specific medications within drug classes in our analysis, it is clear from previous research that medications within drug classes differ regarding the risk of weight gain associated with their use.[34–36] The risk of weight gain associated with specific medications within a drug class would be one of the factors GPs discuss with their patients when initiating therapy, especially for those with other risk factors for obesity. However, switching medication to assist with weight management would require very careful consideration and consultation with the patient and other healthcare professionals involved regarding potential risks and benefits, including the risk of relapse of the indicator condition.[34]

There is a large and growing proportion of Australians with obesity.[6] For the majority of patients requiring obesity prevention and management, this is best provided by the general practice and primary care teams which are more accessible than specialist care.[12,33,37] Though Medicare funds bariatric surgery for severe obesity and its use is increasing in Australia,[38,39] there is limited access for those who have not reached that stage of severity and do not have private health insurance cover. While there is evidence on the beneficial effects of dietetic consultations and regular exercise on weight management[40,41]; the availability of dietetic and exercise physiology consultations may be limited by the need for other allied health consultations for other chronic conditions under team care arrangements.[11] Notably, allied health consultations regarding obesity are subsidised by Medicare only when the patient has other chronic conditions (e.g. diabetes) under team care arrangements.[12,33] Unfortunately, "uncomplicated" obesity does not qualify for Medicare subsidised allied health consultations, making access difficult for patients on low incomes.[12,33] While our study found an association between allied health service use through team care planning and developing obesity, this service use was likely for the management of other chronic conditions not weight.

We agree with the World Health Organisation, numerous health professional organisations and other authors that obesity should be classified as a chronic disease, rather than a chronic disease risk factor, as failing to do so prohibits many patients with obesity from qualifying for structured funded management plans.[42,43] We recommend that patients with obesity should have access to funded chronic disease management plans as do other patients with chronic disease.[11,42] We also recommend implementation of comprehensive public health campaigns that seek to de-stigmatise discussing obesity, address the obesogenic environment, highlight the benefits of returning to a healthy weight, and urge those with obesity to see their primary care clinician to access the care they need.[12,33]

Strengths and limitations To the best of our knowledge, this is the first study to include past personal history of chronic health conditions, allied health service use through team care planning, and medication usage when assessing risk factors for developing obesity. The major strength of this study was our use of a large community-dwelling cohort of older adults, which was not restricted only to those engaged with health services, thus providing a more realistic denominator. Recruitment of individuals across the age spectrum from 45 to 90 years to the 45 and Up Study at baseline enabled us to assess the impacts on older people in the community.

Our study also has several potential limitations. While the 45 and Up Study is the largest study of its kind in the southern

hemisphere, it was not designed to be representative of the general population.[19] Though non-response at baseline may mean the cohort varies slightly from the broader population, comparison of these rates over time and between subgroups is still valid and should be applicable to those groups within the broader population.[19, 44] Another potential limitation is using the baseline survey to identify the number of chronic health conditions through self-report. However, a recent Australian study exploring the concordance between the 45 and Up Study baseline survey and administrative healthcare datasets, found that over 70% of individuals classified as having multimorbidity were identified in the baseline survey.[45] Since our study involved comparing BMI at baseline and the first follow-up, the study needed to be limited to those who had completed both surveys with 65% of the cohort responding to the first follow-up. While this could potentially introduce bias, Wang and colleagues found the participants' nonresponse did not result in substantial bias and did not alter the interpretation of results in general.[46] Our study was restricted to metropolitan Sydney, which limits its generalisability. We made that decision because of differences between rural and urban areas and because of our close working relationship with service providers in metropolitan Sydney.

We found an association between allied health service use through team care planning and developing obesity and, despite including multiple variables known to be associated with obesity to adjust for confounding in our analysis, there may be residual confounding. This may also occur if variables used to control for confounding are subject to misclassification and/or response bias. We also cannot be sure of the temporality of developing obesity and allied health service use—it is possible that developing obesity may have preceded allied health service use between the baseline and follow-up surveys.

The British Association for Psychopharmacology (BAP) classifies several antipsychotic drugs (amisulpride, aripiprazole, ziprasidone, haloperidol, lurasidone, and asenapine) as being low risk for weight gain.[34] However, we used the Australian Medicines Handbook, an independent clinical resource that is readily available in primary care, to identify and categorise medications that are associated with weight gain for inclusion in our analyses.[24] In the Australian Medicine Handbook, weight gain is listed as a common adverse side effect for all antipsychotic drugs.[24] That said, we used the list of antipsychotics classified as low risk for weight gain by BAP to check for any impact of misclassification on our findings. The number of people taking antipsychotic drugs with low risk for weight gain was small (<50 in each group in our cohort) and recategorising them had little impact on the effect size and confidence intervals regarding whether psychotropic drugs as a class (which includes drugs other than antipsychotics) were associated with developing obesity (data not shown). The classification of medications can be difficult. Furthermore, some medications have multiple indications. For example, the tricyclic antidepressant, amitriptyline was analysed as a psychotropic but is also used to manage neuropathic pain.[47] Hence, there is a possibility of non-differential misclassification and thus more conservative relative risk estimates.

Implications for research and practice Effective obesity prevention strategies are an urgent priority. This study identified key characteristics of older patients who are at risk of developing obesity, including risk behaviours (smoking and physical inactivity) and chronic conditions or their treatment (self-report of two or more chronic conditions, physical function, psychological distress, and use of anti-epileptic medications). These findings may help alert clinicians to the need for preventive interventions in selected cases as well as informing the targeting of public health programs.

Acknowledgements

The research was completed using data collected through the 45 and Up Study (www.saxinstitute.org.au/our-work/45-up-study/). The 45 and Up Study is managed by the Sax Institute in collaboration with major partner Cancer Council NSW; and partners the Heart Foundation and NSW Ministry of Health. We thank the many thousands of people participating in the 45 and Up Study. We acknowledge the NSW Centre for Health Record Linkage (CHeReL) for probabilistic linkage and provision of the deaths data (http://www.cherel.org.au/); and the Sax Institute for facilitating linkage with Medicare claims data and Pharmaceutical Benefits Scheme (PBS) data supplied by Services Australia using a unique identifier and deterministic matching. We also acknowledge the Sax Institute's Secure Unified Research Environment (SURE) for the provision of secure data access.

Supplementary material

Supplementary material is available at *Family Practice* online.

Ethical Approvals

This research was approved by the New South Wales Population and Health Services Research Ethics Committee (2016/06/642) and the 45 and Up Study overall was approved by the University of New South Wales Human Research Ethics Committee.

Funding

This research was funded by Sydney Local Health District, South Eastern Sydney Local Health District and the Central and Eastern Sydney Primary Health Network. MB, AK and MW's positions were supported by the funding partners. The Central and Eastern Sydney Primary and Community Health Cohort/Linkage Resource management group includes representatives from each of the funding partners. The management group oversees which projects are conducted using the Resource and provides input into the overall design, interpretation of the results and knowledge translation opportunities.

Conflict of interest

The authors declare no potential conflicts of interest.

Data Availability

Data that support the findings of this study are available from the Sax Institute, but restrictions apply to the availability of these data, which were used under licence for the current study and so are not publicly available. The data, however, are available from the authors upon reasonable request and with permission from the Sax Institute.

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