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Can regular long-term breakfast cereals consumption benefits lower cardiovascular diseases and diabetes risk? A longitudinal population-based study

Xiaoyue Xu, PhD, MPH, MSc, BN [a, *], Deborah Parker, PhD, MSocSc, BA [a], Sally C. Inglis, PhD, BHScHons, BN [a], Julie Byles, PhD, BMed [b]

[a] Faculty of Health, University of Technology Sydney, Ultimo, New South Wales, Australia
[b] Priority Research Centre for Generational, Health and Ageing, School of Medicine and Public Health, Hunter Medical Research Institute, University of Newcastle, New Lambton Heights, New South Wales, Australia

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ABSTRACT

Purpose: Studies indicate breakfast cereals may reduce the risk of overweight, cardiovascular diseases, and diabetes, but a limited number of longitudinal studies have explored these relationships, indicating the need for further assessment.
Methods: We used 45 and Up Study data to examine the longitudinal association between breakfast cereals (and different categories of cereals) and heart disease, stroke, and diabetes. Dietary consumption was assessed by a short food frequency questionnaire. Diagnosed heart disease, stroke, and diabetes were self-reported. Generalized estimating equation models were used to examine the longitudinal associations.
Results: Of a total of 142,503 participants (aged 45 years and older), people in the older age group (aged 80 or older) had significantly higher breakfast cereal consumption ($P < .001$) than those in the younger age group (aged 45–64 years). A significantly inverse association was found between breakfast muesli and heart disease, stroke, and diabetes across all age groups. Associations between other categories of breakfast cereals (biscuit, bran, and oat cereals) and these three diseases differed by age groups. A positive association was found between oat cereals and diabetes for people in the younger age groups (aged 80 years and younger), but not for people in the older age group (aged 80 years and older).
Conclusions: The benefit of breakfast muesli consumption was highlighted in prevention of these three diseases. The result suggests that age-specific dietary guidelines, with a particular focus on the types of breakfast cereals consumption in prevention of chronic diseases for older people need to be developed.

Introduction

The Australia population is rapidly aging. In 2016, over 1 in 7 people were aged 65 years and older and this population is projected to more than double by 2050 [1]. As chronic and degenerative diseases are more common for older adults, this will result in an increased prevalence of chronic diseases at the population level [2,3].

Cardiovascular disease (CVD) includes conditions such as coronary heart disease, heart failure, cardiomyopathies, congenital heart disease, peripheral arterial disease, and stroke [4]. It remains a major cause of mortality worldwide [5] and is the leading cause of death and disease burden in Australia. The prevalence of diabetes also increases rapidly with age. Based on Australian Bureau of Statistics, an estimated 1.2 million Australian adults aged 18 years and older have diabetes, with people aged 65–74 years three times more likely to have diabetes than people aged 45–54 years [6]. Cardiovascular diseases and diabetes are long-lasting conditions causing more illness, disability, and premature death, which impacts on peoples' quality of life and results in substantial spending on health.

Chronic diseases can be prevented through population health approaches, targeted at modifiable risk factors, such as healthy diet [7]. There is growing interest in exploring the benefits of cereals

Conflict of interest: The authors declare that they have no conflict of interest.

* Corresponding author: Faculty of Health, University of Technology Sydney, Level 7, Building 10, Broadway, New South Wales 2007 Australia. Tel.: +61 2 9514 5972.
E-mail address: xiaoyue.xu@uts.edu.au (X. Xu).

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consumption, as it provides important amounts of most nutrients, such as fiber, iron, zinc, and vitamins. Breakfast cereal can be defined as a grain-based food product usually made from oats, rice, wheat, or corn, which may be minimally processed, such as drying and rolling the grain (e.g., rolled oats), or cooked and flaked or puffed [8]. Cereal is often consumed with milk or yogurt. Studies have indicated that consumption of cereals or cereal fiber is protective against development of obesity [8,9]; and lower levels of a variety of risk factors, such as CVDs, type II diabetes, and certain cancers [10,11].

Most studies exploring the association between breakfast cereals and health outcomes are cross-sectional [11,12]. Two systematic reviews and meta-analyses examine whole-grain breakfast cereals consumption in relation to risk of cardiovascular disease, mortality, and type II diabetes in longitudinal studies [13,14]. However, further cohort studies are needed because of the limited number of studies on whole-grain breakfast cereals. In addition, few studies have focused on the older population [15]. People are often encouraged to eat cereals [16]; but it is unclear what is the healthiest breakfast cereal in terms of preventing CVDs and diabetes, especially for older people. Therefore, the specific aims of the present study were 1) to understand breakfast cereals (and different categories of cereals) consumption by socioeconomic and health behavior factors and 2) to examine the longitudinal associations between breakfast cereal consumption and CVDs, as well as diabetes for older Australians.

Methods

45 and Up Study

We analyzed The Sax Institute's 45 and Up Study data to address our research aims. The 45 and Up Study is the largest ongoing study of healthy aging ever undertaken in the Southern Hemisphere [17]. Prospective participants were randomly sampled from the Department of Human Services (formerly Medicare Australia) enrollment database, which provides near complete coverage of the population. A total of 267,153 men and women aged 45 years and older across New South Wales, Australia, were surveyed in 2006–2009. The first follow-up survey data were collected between 2012 and 2015. Detailed of the 45 and Up Study sampling process are described elsewhere [18].

Dietary consumption and outcomes

Dietary consumption was assessed by asking the participants the frequency of fruit and vegetable, red meat, chicken, processed meat, fish or seafood, cereal, and cheese consumption per week; and assessed by the amount of vegetable and fruit consumption and the type of cereal and milk. The types of cereals include bran cereals (all-bran, branflakes, etc), biscuit cereals (weetbix, shredded wheat, etc), muesli, oat cereals (porridge, etc), and others.

For analysis, breakfast cereals consumption was categorized as variables: 1) usually eat breakfast cereals (any) YES/NO; 2) usually eat biscuit cereals YES/NO; 3) bran cereals YES/NO; 4) muesli YES/NO; and 5) oat cereals YES/NO. The category of "others" was not included in the analysis. These variables were not mutually exclusive, and people could eat more than one type of cereal.

The main outcome variables were heart disease, stroke, and diabetes as reported on each survey in response to the question 'has a doctor ever told you that you have … ".

Covariates

Sociodemographic factors included in this study were age, sex (male/female), marital status (married/partner; single/divorce/separated; widowed), qualification (low: no school certificate or other qualification, and school or intermediate certificate; medium: high school or leaving certificate; and trade or apprenticeship; and high: certificate or diploma, and university degree or higher), and Socio-Economic Indexes For Areas (SEIFA: low, median, and high) based on three quantiles from Index of Relative Socioeconomic Advantage and Disadvantage [19].

Health behavior factors included smoking, drinking, and physical activity levels. Smokers were identified based on the question "are you a regular smoker now?" Alcohol consumption was allocated to two categories (Yes/No), with the question "about how many alcoholic drinks do you have each week?" Physical activity was assessed via The Active Australia Survey, wherein participants self-reported minutes spent walking or doing moderate or vigorous physical activities over the previous week [20]. We further allocated the physical activity level to "inadequate" and "adequate" based on the Australia's Physical Activity and Sedentary Behavior Guidelines [21].

Statistical analysis

Generalized estimating equation was used to examine the statistical difference between different categories of breakfast cereals consumption (any, biscuit, bran, muesli, and oat) and socioeconomic factors, as well as health behavior variables. χ^2 test was used to assess the statistical difference between percentages of heart disease, stroke, and diabetes and age groups for each survey. Generalized estimating equation models were used to examine the longitudinal association between different categories of breakfast cereals consumption and heart disease, stroke, and diabetes. As age is the potential confounder or effect modifier on the association between breakfast cereals and chronic diseases, we therefore stratified by age groups (i.e., aged 45–64 years, 65–80 years, and 80 years or older) in our analysis. All analyses were conducted in STATA/SE 14 (StataCorp).

Ethics

The conduct of the 45 and Up Study was approved by the University of New South Wales Human Research Ethics Committee. Analysis of the 45 and Up Study for the present study was approved by The University of Technology, Sydney (ETH18-2145).

Results

A total of 142,503 participants, who completed both baseline and follow-up questionnaire, were included in the analysis (285,006 observations). Table 1 shows the different categories of breakfast cereals consumption by socioeconomic and health behavior variables. In general, 16.2% of participants reported having no breakfast cereals consumption; 76.3% of participants reported no biscuit cereals consumption; 86.2% of participants reported no bran cereals consumption; 75.6% of participants reported no muesli consumption; and 76.2% of participants reported no oat cereals consumption. Thirty-five percent of the participants were former smokers; five percent were current smokers. Gender, marital status, and physical activity levels were significantly associated with all five categories of breakfast cereals consumption ($P \leq .01$). Figure 1 shows age associated increase in the percentage of people reporting stroke and diabetes and heart disease at the baseline and follow-up.

Table 1
Breakfast cereals consumption by socioeconomic and health behavior variables (n = 142,503, with 285,006 observations)

Variables	Breakfast cereals	P value‖	Biscuit cereals	*P* value‖	Bran cereals	*P* value‖	Muesli	*P* value‖	Oat cereals	*P* value‖
Age groups	N (%)	—	N (%)	—	N (%)	—	N (%)	—	N (%)	—
45–64 y	127,831 (81.4)	—	39,123 (23.8)	—	22,993 (14.0)	—	44,171 (26.9)	—	37,626 (22.9)	—
65–80 y	79,461 (86.4)	<.001	23,122 (23.8)	<.001	13,341 (13.7)	<.001	21,498 (22.1)	<.001	24,203 (24.9)	.001
80 y or above	19,429 (91.2)	<.001	5216 (22.4)	<.001	3051 (13.1)	<.001	3882 (16.7)	<.001	5967 (25.7)	.83
Gender	—	—	—	—	—	—	—	—	—	—
Male	103,150 (84.9)	—	36,418 (28.5)	—	17,915 (14.0)	—	28,383 (22.2)	—	25,408 (19.9)	—
Female	123,578 (83.0)	<.001	31,045 (19.8)	<.001	21,470 (13.7)	.01	41,171 (26.2)	<.001	42,389 (27.0)	<.001
Marital status	—	—	—	—	—	—	—	—	—	—
Married/partner	174,289 (84.3)	—	52,303 (24.1)	—	31,149 (14.4)	—	54,640 (25.1)	—	50,734 (23.4)	—
Single/divorce/separated	32,599 (79.8)	<.001	9411 (21.7)	<.001	5141 (11.8)	<.001	10,148 (23.4)	<.001	10,641 (24.5)	<.001
Widowed	18,195 (87.6)	<.001	5274 (23.6)	<.001	2826 (12.6)	<.001	4500 (20.1)	<.001	5972 (26.7)	<.001
Qualification*	—	—	—	—	—	—	—	—	—	—
Low	63,317 (83.9)	—	21,201 (26.3)	—	12,045 (14.9)	—	14,084 (17.5)	—	20,193 (25.0)	—
Medium	95,708 (83.8)	.46	29,325 (24.4)	<.001	16,675 (13.9)	<.001	28,517 (23.7)	<.001	28,835 (24.0)	<.001
High	65,582 (83.8)	.73	16,246 (20.0)	<.001	10,254 (12.6)	<.001	26,493 (32.6)	<.001	18,088 (22.3)	<.001
SEIFA§	—	—	—	—	—	—	—	—	—	—
Low	67,804 (83.0)	—	21,416 (24.7)	—	11,689 (13.5)	—	17,509 (20.2)	—	21,068 (24.3)	—
Medium	72,942 (83.9)	<.001	22,428 (24.5)	.44	12,850 (14.0)	<.001	21,696 (23.7)	<.001	22,210 (24.3)	.24
High	76,415 (84.6)	<.001	21,161 (22.4)	<.001	13,408 (14.2)	<.001	27,301 (28.9)	<.001	21,899 (23.2)	.001
BMI†	—	—	—	—	—	—	—	—	—	—
Underweight	2443 (81.6)	<.01	617 (19.2)	<.001	365 (11.3)	<.01	763 (23.7)	<.001	812 (25.2)	.15
Normal	54,804 (84.5)	—	14,648 (21.5)	—	8927 (13.1)	—	19,712 (28.9)	—	17,823 (26.2)	—
Overweight	76,212 (85.5)	<.001	23,503 (25.2)	<.001	13,695 (14.7)	<.001	24,208 (25.9)	<.001	22,535 (24.1)	<.001
Obesity	69,644 (81.7)	<.001	22,384 (25.0)	<.001	12,814 (14.3)	<.001	18,749 (20.9)	<.001	20,112 (22.4)	<.001
Current smoker	—	—	—	—	—	—	—	—	—	—
No	217,146 (84.7)	—	63,957 (23.7)	—	37,798 (14.0)	—	67,306 (25.0)	—	65,389 (24.3)	—
Yes	8238 (66.1)	<.001	3154 (23.3)	.38	1379 (10.2)	<.001	1936 (14.3)	<.001	2049 (15.2)	<.001
Former smoker	—	—	—	—	—	—	—	—	—	—
No	147,871 (84.2)	—	44,030 (24.0)	—	25,385 (13.9)	—	45,999 (25.1)	—	45,565 (24.9)	—
Yes	77,374 (82.1)	<.001	23,046 (23.1)	<.001	13,766 (13.8)	.90	23,290 (23.3)	<.001	21,834 (21.9)	<.001
Alcohol drinking	—	—	—	—	—	—	—	—	—	—
No	68,105 (83.9)	—	20,693 (24.2)	—	11,167 (13.0)	—	16,708 (19.5)	—	23,773 (27.8)	—
Yes	155,073 (83.8)	.46	45,764 (23.6)	.24	27,637 (14.2)	<.001	52,068 (26.8)	<.001	42,874 (22.1)	<.001
Physical activity‡	—	—	—	—	—	—	—	—	—	—
Inadequate	151,155 (83.8)	—	50,304 (26.4)	—	29,713 (15.6)	—	47,597 (24.9)	—	50,002 (26.2)	—
Adequate	74,637 (83.9)	<.001	16,786 (18.1)	<.001	9456 (10.2)	<.001	21,637 (23.3)	<.001	17,394 (18.7)	<.001

GEE = generalized estimating equation.

* Low: No school certificate or other qualification, and school or intermediate certificate; Medium: High school or leaving certificate; and trade or apprenticeship; High: Certificate or diploma, and university degree or higher.

† underweight: < 18.5 kg m^{-2}; normal: 18.5–23.9 kg m^{-2}; overweight: 24.0–27.9 kg m^{-2}; general obesity: ≥ 28.0 kg m^{-2}.

‡ Inadequate: 150 minutes of moderate intensity physical activity or 75 minutes of vigorous intensity physical activity per week.

§ Socioeconomic indexes for areas: Three tertiles from Index of Relative Socio-economic Advantage and Disadvantage.

‖ GEE was used to examine the association between different types of cereals consumption and socioeconomic and health behavior variables.

Supplementary Tables 1–3 shows the longitudinal association between different categories of breakfast cereals and heart disease, stroke, and diabetes. After adjustment for socioeconomic factors (in particular age), odds ratio (OR) increased or decreased by at least 10%, which indicated that age is an effect modifier or confounder that can impact on heart disease, stroke, and diabetes. Therefore, the analyses were stratified by age groups.

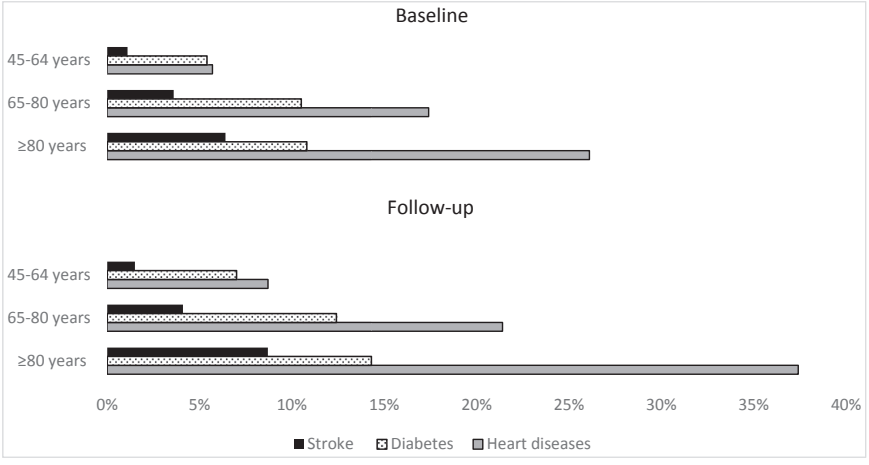

Fig. 1. Percentage of participants reporting stroke and diabetes and heart disease at the baseline and follow-up by age groups.

Table 2 shows the longitudinal association between different categories of breakfast cereals and heart disease by age groups. After adjusting for socioeconomic and health behavior factors (model 3), significantly inverse associations were found between biscuit, bran, and oat cereals and heart disease across different age groups. Breakfast muesli was significantly inversely associated with heart disease across all age groups ($P < .01$). Biscuit cereals were inversely associated with heart disease for people aged 65–80 years (OR = 0.93, 95% CI: 0.89; 0.97) and those aged 80 years or older (OR = 0.92, 95% CI: 0.86; 0.99), but not for the 45–64 group; bran cereals were associated with lower odds of heart disease for people who aged 65–80 years (OR = 0.91, 95% CI: 0.86; 0.95) and for people aged 80 years or older (OR = 0.88, 95% CI: 0.80; 0.96); and oat cereals were associated with lower odds of heart disease for people who aged 80 years or older (OR = 0.92; 95% CI: 0.86; 0.99). Among people aged 45–64 years, there was significant statistical confounding of the association between oat cereals and heart disease by BMI. We therefore conducted a stratification analysis for people in this age group. In this analysis, a significantly positive association was found between oat cereals and heart disease for people who had normal BMI and who were aged 45–64 years (OR = 1.14, 95% CI: 1.02; 1.27), but not for the other BMI groups.

Table 3 shows the longitudinal relationship between different categories of breakfast cereals and stroke by age groups. In model 3, we found no significant associations between biscuit cereals and stroke. However, significantly inverse associations were found between muesli and stroke across all age groups ($P < .01$). Significant inverse associations were also found between bran cereals and stroke for people in the younger age group (OR = 0.81; 95% CI: 0.70; 0.94), and between oat cereals and stroke for people in the older age group (OR = 0.79; 95% CI: 0.69; 0.90).

Table 4 shows the longitudinal relationship between different categories of breakfast cereals and diabetes by age groups. In model 3, we found significant associations between breakfast muesli and diabetes across all age groups ($P < .01$), and between bran cereals and diabetes for people who were aged 65–80 years (OR = 0.93; 95% CI: 0.88; 0.98). However, compared with people who did not eat oat cereals, people who ate oat cereals had higher odds for diabetes (OR = 1.20; 95% CI: 1.14; 1.26) for people who aged 45–64 years, and OR = 1.06 (95% CI: 1.01; 1.11) for people who aged 65–80 years. After adjustment of other key food groups (fruit, vegetable, red meat, and processed meat), these associations were generally the same (Tables 2–4, model 4).

The post hoc supplementary analysis was carried out where we excluded the people who had CVD and diabetes at the baseline to test association between cereal consumption at the baseline and new diseases at follow-up with results being similar (see Supplementary Tables 4–6). Breakfast muesli and bran cereals were significantly inversely associated with the incidence of heart disease, stroke, and diabetes. A significant inverse association was also found between oat cereals and the incidence of these three diseases. Among people who had no CVD and diabetes at the baseline, but had CVD and diabetes at follow-up, there was significantly decrease of breakfast cereals consumption across the two survey points (Supplementary Table 7).

Sensitivity analysis

We also tested whether the people who did not complete the follow-up were different according to their consumption of breakfast cereal and heart disease, stroke, and diabetes, and we included this group (n = 124,823) in the sensitivity analysis. The results showed that although the associations between other categories of breakfast cereals (any breakfast, biscuit, bran, and oat cereals) and these three diseases differed by age group, a significant inverse association was found between breakfast

Table 2
Longitudinal association between breakfast cereals consumption and heart disease by age groups*

Heart disease	Age groups					
	45–64 y		65–80 y		80 y or above	
	OR (95% CI)	*P* Value	OR (95% CI)	*P* Value	OR (95% CI)	*P* Value
Any breakfast cereal						
Model 1	0.94 (0.89; 0.98)	.01	1.04 (0.10; 1.10)	.07	1.04 (0.94; 1.15)	.45
Model 2	0.91 (0.86; 0.96)	<.001	0.98 (0.93; 1.03)	.49	0.97 (0.87; 1.08)	.63
Model 3	0.95 (0.90; 1.00)	.05	1.04 (0.99; 1.10)	.13	0.98 (0.87; 1.10)	.73
Model 4	0.93 (0.88; 0.99)	.03	1.02 (0.96; 1.08)	.48	0.99 (0.87; 1.13)	.88
Biscuit cereals						
Model 1	0.98 (0.94; 1.03)	.05	0.96 (0.93; 0.99)	.05	0.91 (0.85; 0.97)	<.01
Model 2	0.98 (0.94; 1.03)	.41	0.97 (0.93; 1.01)	.08	0.96 (0.90; 1.03)	.25
Model 3	0.96 (0.91; 1.00)	.07	0.93 (0.89; 0.97)	.001	0.92 (0.86; 0.99)	.03
Model 4	0.98 (0.94; 1.04)	.64	0.97 (0.93; 1.02)	.24	0.98 (0.90; 1.07)	.69
Bran cereals						
Model 1	0.89 (0.84; 0.94)	<.001	0.89 (0.85; 0.93)	<.001	0.88 (0.81; 0.95)	.001
Model 2	0.98 (0.93; 1.05)	.67	0.93 (0.89; 0.98)	.005	0.94 (0.87; 1.02)	.15
Model 3	0.94 (0.89; 1.00)	.06	0.91 (0.86; 0.95)	<.001	0.88 (0.80; 0.96)	<.01
Model 4	0.96 (0.90; 1.03)	.26	0.92 (0.87; 0.98)	.007	0.92 (0.83; 1.01)	.09
Muesli						
Model 1	0.82 (0.79; 0.86)	<.001	0.80 (0.77; 0.83)	<.001	0.85 (0.79; 0.91)	<.001
Model 2	0.91 (0.87; 0.95)	<.001	0.89 (0.85; 0.92)	<.001	0.89 (0.83; 0.96)	.006
Model 3	0.92 (0.87; 0.97)	<.001	0.86 (0.83; 0.90)	<.001	0.87 (0.80; 0.95)	.002
Model 4	0.94 (0.89; 0.99)	<.02	0.89 (0.86; 0.94)	<.001	0.86 (0.78; 0.94)	.002
Oat cereals						
Model 1	0.93 (0.89; 0.97)	.001	0.93 (0.89; 0.96)	<.001	0.91 (0.85; 0.96)	.001
Model 2	0.99 (0.95; 1.04)	.86	1.01 (0.98; 1.05)	.51	0.96 (0.90; 1.02)	.21
Model 3	1.06 (1.01; 1.13)	.02	1.01 (0.96; 1.04)	.86	0.92 (0.86; 0.99)	.02
Model 4	1.03 (0.98; 1.08)	.28	1.02 (0.98; 1.07)	.34	0.94 (0.87; 1.02)	.14

* Model 1 is the crude model; model 2 after adjusted for gender, marital status, education level, SEIFA, alcohol drinking, smoking and physical activity levels; model 3 adjusted for BMI and model 2; model 4 adjusted for fruit, vegetable, red meat and processed meat consumption and model 3.

Table 3
The longitudinal relationship between different types of breakfast cereals and stroke by age groups*

Stroke	Age groups					
	45–64 y		65–80 y		80 y or above	
	OR (95% CI)	*P* Value	OR (95% CI)	*P* Value	OR (95% CI)	*P* Value
Any breakfast cereal						
Model 1	0.88 (0.79; 0.98)	.02	1.02 (0.92; 1.12)	.71	1.00 (0.84; 1.19)	.99
Model 2	0.90 (0.80; 1.01)	.07	0.93 (0.84; 1.03)	.16	1.02 (0.84; 1.23)	.85
Model 3	0.93 (0.82; 1.05)	.25	1.00 (0.90; 1.12)	.97	1.01 (0.82; 1.25)	.93
Model 4	0.91 (0.79; 1.05)	.19	0.95 (0.83; 1.07)	.37	1.05 (0.84; 1.32)	.66
Biscuit cereals						
Model 1	1.04 (0.95; 1.15)	.40	0.95 (0.89; 1.03)	.22	1.03 (0.92; 1.15)	.60
Model 2	1.07 (0.96; 1.18)	.22	0.96 (0.90; 1.04)	.34	1.06 (0.95; 1.20)	.30
Model 3	1.03 (0.93; 1.15)	.55	0.93 (0.85; 1.01)	.07	1.02 (0.90; 1.16)	.75
Model 4	1.06 (0.94; 1.20)	.35	0.96 (0.88; 1.06)	.47	1.13 (0.98; 1.31)	.09
Bran cereals						
Model 1	0.79 (0.69; 0.89)	<.001	0.92 (0.84; 1.01)	.08	0.84 (0.73; 0.97)	.02
Model 2	0.85 (0.74; 0.97)	<.02	0.95 (0.86; 1.04)	.26	0.89 (0.77; 1.04)	.14
Model 3	0.81 (0.70; 0.94)	<.01	0.94 (0.85; 1.04)	.24	0.87 (0.74; 1.02)	.09
Model 4	0.84 (0.71; 0.99)	<.04	0.91 (0.81; 1.03)	.15	0.93 (0.77; 1.11)	.42
Muesli						
Model 1	0.76 (0.69; 0.84)	<.001	0.72 (0.67; 0.79)	<.001	0.80 (0.70; 0.91)	.001
Model 2	0.85 (0.76; 0.95)	.003	0.82 (0.75; 0.90)	<.001	0.89 (0.77; 1.03)	.12
Model 3	0.86 (0.77; 0.97)	.01	0.78 (0.71; 0.86)	<.001	0.82 (0.70; 0.96)	.01
Model 4	0.85 (0.75; 0.97)	<.02	0.79 (0.71; 0.88)	<.001	0.88 (0.74; 1.04)	.14
Oat cereals						
Model 1	0.86 (0.78; 0.95)	<.01	0.92 (0.85; 0.99)	.02	0.82 (0.73; 0.91)	<.001
Model 2	0.90 (0.81; 1.00)	.06	0.96 (0.89; 1.04)	.30	0.82 (0.73; 0.93)	.001
Model 3	0.93 (0.83; 1.05)	.24	0.95 (0.88; 1.04)	.27	0.79 (0.69; 0.90)	<.001
Model 4	0.91 (0.80; 1.04)	.16	0.98 (0.89; 1.08)	.72	0.82 (0.71; 0.96)	.01

* Model 1 is the crude model; model 2 after adjusted for gender, marital status, education level, SEIFA, alcohol drinking, smoking and physical activity levels; model 3 adjusted for BMI and model 2; model 4 adjusted for fruit, vegetable, red meat and processed meat consumption and model 3.

muesli and heart disease (OR = 0.92; 95% CI: 0.89; 0.97), stroke (OR = 0.92; 95% CI: 0.75; 0.89), and diabetes (OR = 0.79; 95% CI: 0.75; 0.84), which was consistent with our longitudinal analysis results.

Discussion

Our results showed differences in the consumption of breakfast cereal, and type of breakfast cereal, according to age and

Table 4
The longitudinal relationship between different types of breakfast cereals and diabetes by age groups*

Diabetes	Age groups					
	45–64 y		65–80 y		80 y or above	
	OR (95% CI)	*P* Value	OR (95% CI)	*P* Value	OR (95% CI)	*P* Value
Any breakfast cereal						
Model 1	0.99 (0.95; 1.04)	.75	0.99 (0.94; 1.05)	.83	1.07 (0.94; 1.22)	.32
Model 2	0.99 (0.94; 1.04)	.59	0.94 (0.89; 1.00)	.05	1.03 (0.90; 1.19)	.64
Model 3	1.02 (0.97; 1.08)	.43	1.00 (0.94; 1.07)	.95	1.12 (0.95; 1.32)	.16
Model 4	0.99 (0.94; 1.06)	.98	0.96 (0.90; 1.03)	.31	1.12 (0.93; 1.34)	.24
Biscuit cereals						
Model 1	1.05 (1.00; 1.09)	.03	1.00 (0.96; 1.04)	.96	1.05 (0.97; 1.13)	.26
Model 2	1.07 (1.03; 1.12)	.001	1.02 (0.98; 1.06)	.39	1.06 (0.97; 1.15)	.19
Model 3	1.02 (0.97; 1.07)	.38	0.98 (0.94; 1.03)	.49	1.03 (0.93; 1.13)	.58
Model 4	1.06 (1.01; 1.12)	.03	0.99 (0.95; 1.05)	.99	1.03 (0.93; 1.15)	.55
Bran cereals						
Model 1	0.91 (0.87; 0.96)	.001	0.90 (0.85; 0.94)	<.001	0.96 (0.87; 1.05)	.34
Model 2	0.98 (0.93; 1.03)	.48	0.94 (0.89; 0.99)	<.02	0.94 (0.85; 1.04)	.22
Model 3	0.95 (0.89; 1.01)	.08	0.93 (0.88; 0.98)	.01	0.91 (0.81; 1.02)	.11
Model 4	0.98 (0.92; 1.05)	.56	0.97 (0.91; 1.03)	.34	0.87 (0.76; 0.99)	.05
Muesli						
Model 1	0.73 (0.70; 0.76)	<.001	0.73 (0.70; 0.76)	<.001	0.78 (0.71; 0.85)	<.001
Model 2	0.84 (0.81; 0.88)	<.001	0.80 (0.77; 0.84)	<.001	0.84 (0.76; 0.93)	.001
Model 3	0.85 (0.81; 0.90)	<.001	0.79 (0.75; 0.84)	<.001	0.84 (0.75; 0.95)	.004
Model 4	0.84 (0.79; 0.89)	<.001	0.79 (0.74; 0.84)	<.001	0.84 (0.74; 0.96)	.01
Oat cereals						
Model 1	1.08 (1.03; 1.12)	<.001	0.98 (0.94; 1.01)	.21	0.99 (0.93; 1.08)	.99
Model 2	1.13 (1.08; 1.18)	<.001	1.03 (0.98; 1.07)	.15	0.99 (0.92; 1.08)	.9
Model 3	1.20 (1.14; 1.26)	<.001	1.06 (1.01; 1.11)	.01	1.05 (0.96; 1.15)	.28
Model 4	1.17 (1.11; 1.23)	<.001	1.08 (1.03; 1.14)	.003	1.12 (1.01; 1.24)	.04

* Model 1 is the crude model; model 2 after adjusted for gender, marital status, education level, SEIFA, alcohol drinking, smoking and physical activity levels; model 3 adjusted for BMI and model 2; model 4 adjusted for fruit, vegetable, red meat and processed meat consumption and model 3.

socioeconomic status. Our results showed the association between different type of breakfast cereals consumption and CVD and diabetes risk and highlighted the benefit of the breakfast muesli in prevention of heart disease, stroke, and diabetes across all age groups for older Australians.

Older people were generally more likely to eat breakfast cereal (of any type) and were less likely to eat muesli and more likely to eat oats compared with younger groups. Our result is similar to data from the Australian Health Survey [22]; which showed that compared with people aged 51–70 years, people aged 71 years or over had higher percentage of consuming breakfast cereals (49.8% vs. 36.4%). The different choices of cereal may be linked to prevailing trends in food availability for different birth cohorts or may be related to the texture of these cereals. For instance, muesli (commonly with nuts and dry fruit) may be difficult for older people to chew and requires extensive mastication for older people [23].

Our study showed that socioeconomic factors were significantly related to the choice of different types of breakfast cereals consumption for older people. Although there are limited studies exploring different types of breakfast cereal consumption by socioeconomic factors, previous studies have indicated that there is demographic and socioeconomic disparity in dietary consumption [24]. Women tend to be more invested in food-related issues [25]; have better knowledge and nutrition, and confer greater importance to healthy eating [26]. Marital status is related to food consumption [27] and food-related issues, such as food insecurity [28]. Low levels of education and limited economic resources may contribute to people choosing low-cost, unhealthy, energy-dense foods, which are high in fat and sugar [29].

Our results show that as age increases, the prevalence of heart disease, diabetes, and stroke are significantly increased. However, the prevalence of CVDs and diabetes in our data were significantly lower than the Australian representative data (Australian Bureau of Statistics), which shows that 53% of people aged 65–74 years had CVDs, and 66% of people who aged 75 years and over had CVDs [30]; 5% of people who aged 45–54 years had diabetes, and the prevalence increased to 17% for people aged 65–74 years in 2014–15 [6].

Considering breakfast cereals as a general group, we did not find significant longitudinal association between eating cereals (regardless of types) and heart disease, stroke, or diabetes. Although previous studies showed the benefits of breakfast cereals in prevention of diseases, the population age and the outcomes of their studies differed from the present study. For instance, data from the 2011–2012 Australian National Nutrition and Physical Activity Survey showed that among people who aged 2–18 years old, regardless of the type of cereals and its sugar content, breakfast cereals consumers had higher intakes of dietary fiber and most micronutrients, which had positive benefits for body weight and nutrition compared with noncereal breakfast consumers [31]. Bazzano et al study showed that over eight years follow-up, males aged 40–84 years who consumed breakfast cereals consistently weighed less than those who consumed breakfast cereals less often [32]. Previous research has also suggested that breakfast cereals consumption was linked with low mortality. The results from NIH-AARP Diet and Health Study showed that there was significant reduction in risk of diabetes and CVD mortality across increasing quartiles of cereal consumption among 367,442 people who were aged 50–71 years in the United States [10].

We found consistent results that muesli was significantly protective against CVD and diabetes for older people across all age groups. Breakfast muesli often contains nuts (such as almonds, hazelnuts, walnuts, pistachios, macadamias, and cashews), along with dried fruit and seeds which may be the key component that is protective against CVD and diabetes. Nuts and dried fruit contain various macro- and micronutrients together with other important bioactive compounds (such as polyphenols, vitamins, minerals, antioxidants, and fiber) which may also contribute to modulate CVDs and specific metabolic diseases, such as diabetes [33–37]. Epidemiological studies have demonstrated that there are consistent findings that nuts and dry fruits are protective against CVDs [33,34,38]; but less research has been undertaken to examine the association between nuts and dried fruit and diabetes. The results from the Nurses' Health Study showed that compared with women who never/almost never consume nuts, women with the highest nut consumption (28 g/day; $\geq$5 days a week) had 0.73 lower relative risk of developing type II diabetes [35]. The results from the National Health and Nutrition Examination Survey showed that decreased insulin resistance and lower level of β-cell function markers were found in the nut consumers than the nonconsumers [34]. A beneficial effect of dried fruit was found on postprandial glucose regulation and glycemic control in people with type II diabetes [37].

Our results also showed the benefit of bran cereals for CVDs and diabetes, and of oat cereals for heart disease and stroke. Bran and oat are important grains in the Western diet [39]; which are usually consumed in whole-grain form. In the bran and whole-grain cereals, bioactive compounds, including phenolic acids and polyphenols, are major compounds for the prevention of CVDs and diabetes [40]. Whole-grain cereals are higher in protein, calcium, essential fatty acids, dietary fiber, including soluble fiber, and mixed linkage β-glucan, which have been shown to reduce low-density lipoprotein cholesterol level [41]. Lowering low-density lipoprotein cholesterol level is a primary goal for CVD prevention. A prospective study that included 86,190 U.S. male physicians aged 45–84 years showed that whole-grain breakfast cereal intake was inversely associated with total and CVD-specific mortality [42]. Two recent systematic reviews and meta-analysis found inverse associations between different types of whole grains and CVDs, mortality, and diabetes [13,14]. The results from Australian Longitudinal Study on Women's Health showed a beneficial role of oat-based cereal, muesli, and All-Bran intakes which was significantly inversely associated with obesity risk among mid-age Australian women [8].

It has been hypothesized that whole-grain breakfast cereals might reduce the risk of diabetes because of their high fiber content and high nutrient density (phytochemicals, vitamins, and minerals). The fiber of whole-grain cereals is hypothesized to improve glycemic response to breakfast, and through this mitigate the development of type II diabetes [43]. A recent systematic review and meta-analysis from 16 studies indicated a beneficial effect of oats intake on glucose control and lipid profiles in type II diabetes [44]. However, our results show that oat cereals were positively associated with diabetes for people who were aged between 45 and 64 years, which was inconsistent with previous literature. We suspected that the main reason for these inconsistent results is that the questionnaire does not distinguish between different forms of oat cereals. Different forms of oat cereals, such as steel-cut oats, large-flake oats, quick-cooking oats, and instant oatmeal, may have different nutritional properties [41]. A systematic review from Tosh and Chu found that glycemic response to porridges made from instant oatmeal was significant higher than that for steel-cut and large-flake oats. The main reason is that instant or quick-cooking oatmeal has more pregelatinized starch. The processing steps for the instant or quick-cooking oatmeal allow the oatmeal to hydrate quickly in boiling water, and it appears to increase the glycemic response. Digestive enzymes easily penetrate the swollen starch granules that are exposed on the large surface area. The increased susceptibility to enzymatic degradation likely accounts for the high glycemic responses of instant or quick-cooking oatmeal porridge [41]. If the 45–64 group has a preference for quick-cooking oats, then this may explain our results in this age group. We are also unable to determine if sugar or other sweeteners were added to the oat cereal.

We do not know the exact frequencies or amount for each type of cereals consumed because our dietary variables were based on the brief questions and not on a food frequency questionnaire or 24-hour recall data. This may limit the accuracy of breakfast cereals consumption assessment. However, a dichotomous variable to explore the association between cereals consumption and health outcomes has been applied in a previous study [8]. We believe our study captures the association between the person's usual type of cereal consumption and CVDs and diabetes risk. Further data collection which includes detailed food consumption questionnaires is needed in this large cohort study.

The strengths of the present study include that we involved a large representative population sample. The longitudinal study assists in making an etiological link between breakfast cereals consumption and CVDs, as well as diabetes. However, there are some limitations need to be recognized. Principally this includes the use of self-reported data. The categories of breakfast cereals cannot provide details of what is actually included in that category. For example, different forms of oat cereals have different impact on glycemic response. The questionnaire does not capture the details of other types of cereals consumption, such as rice-based breakfast cereals or high sugar varieties, and does not have information on how the breakfast cereal was prepared, and what food has been taken along with cereals (e.g., sugar-rich jams or sugar-containing milks). Therefore, it is not possible to evaluate whether these factors would impact on CVDs and diabetes. There was a space for free-text which allowed participants to specify the types of heart disease; however, these free-text data have not been released to researchers yet, which limited us to example the association between breakfast cereals and specific type of heart disease.

Conclusion

Our results highlighted the benefit of the breakfast muesli in prevention of heart disease, stroke, and diabetes across all age groups, but the association between other types of breakfast cereals and CVD as well as diabetes differs across age groups for older Australians. The findings suggest that age-specific healthy dietary guidelines that focus on healthy types of breakfast cereals as part of an overall approach to the prevention of chronic diseases need to be further developed.

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Appendix

Supplementary Table 1
Longitudinal association between breakfast cereals consumption and heart disease*

Heart disease	OR (95% CI)	*P* Value
Any breakfast cereal		
Model 1	1.12 (1.08; 1.15)	<.001
Model 2	0.95 (0.92; 0.98)	.002
Model 3	0.96 (0.93; 0.99)	.04
Model 4	0.97 (0.93; 1.01)	.16
Biscuit cereals		
Model 1	0.89 (0.87; 0.91)	<.001
Model 2	0.97 (0.95; 0.99)	.03
Model 3	0.98 (0.85; 1.01)	.15
Model 4	0.98 (0.95; 1.01)	.17
Bran cereals		
Model 1	0.82 (0.80; 0.85)	<.001
Model 2	0.95 (0.91; 0.98)	.001
Model 3	0.94 (0.91; 0.98)	.001
Model 4	0.93 (0.90; 0.97)	.001
Muesli		
Model 1	0.75 (0.73; 0.77)	<.001
Model 2	0.91 (0.88; 0.94)	<.001
Model 3	0.92 (0.89; 0.95)	<.001
Model 4	0.91 (0.88; 0.95)	<.001
Oat cereals		
Model 1	0.91 (0.88; 0.93)	<.001
Model 2	1.00 (0.97; 1.02)	.77
Model 3	1.02 (0.99; 1.05)	.18
Model 4	1.01 (0.98; 1.05)	.38

* Model 1 is the crude model; model 2 after adjusted for age, gender, marital status, education level, SEIFA alcohol drinking, smoking and physical activity level and model 1; model 3 adjusted for BMI and model 2; model 4 adjusted for fruit, vegetable, red meat and processed meat consumption and model 3.

Supplementary Table 2
The longitudinal relationship between different types of breakfast cereals and stroke*

Stroke	OR (95% CI)	*P* Value
Any breakfast cereal		
Model 1	1.11 (1.04; 1.18)	.002
Model 2	0.95 (0.88; 1.02)	.15
Model 3	0.97 (0.89; 1.04)	.38
Model 4	0.96 (0.88; 1.04)	.31
Biscuit cereals		
Model 1	0.94 (0.89; 0.99)	.01
Model 2	1.02 (0.96; 1.07)	.51
Model 3	1.01 (0.96; 1.07)	.67
Model 4	1.03 (0.96; 1.10)	.41
Bran cereals		
Model 1	0.82 (0.77; 0.88)	<.001
Model 2	0.92 (0.86; 0.99)	.02
Model 3	0.93 (0.86; 0.99)	.05
Model 4	0.91 (0.83; 0.99)	.03
Muesli		
Model 1	0.69 (0.66; 0.73)	<.001
Model 2	0.86 (0.81; 0.91)	<.001
Model 3	0.85 (0.80; 0.91)	<.001
Model 4	0.84 (0.78; 0.90)	<.001
Oat cereals		
Model 1	0.87 (0.83; 0.92)	<.001
Model 2	0.93 (0.88; 0.98)	.07
Model 3	0.95 (0.89; 1.01)	.08
Model 4	0.94 (0.88; 1.01)	<.08

* Model 1 is the crude model; model 2 after adjusted for age, gender, marital status, education level, SEIFA alcohol drinking, smoking and physical activity level and model 1; model 3 adjusted for BMI and model 2; model 4 adjusted for fruit, vegetable, red meat and processed meat consumption and model 3.

Supplementary Table 3
The longitudinal relationship between different types of breakfast cereals and diabetes*

Diabetes	OR (95% CI)	*P* Value
Any breakfast cereal		
Model 1	1.05 (1.01; 1.08)	<.01
Model 2	0.98 (0.94; 1.01)	.24
Model 3	1.00 (0.96; 1.04)	.87
Model 4	0.99 (0.95; 1.03)	.65
Biscuit cereals		
Model 1	0.95 (0.93; 0.98)	<.001
Model 2	1.03 (1.00; 1.06)	.04
Model 3	1.03 (1.00; 1.06)	.05
Model 4	1.01 (0.98; 1.05)	.40
Bran cereals		
Model 1	0.88 (0.86; 0.91)	<.001
Model 2	0.97 (0.93; 0.99)	.03
Model 3	0.97 (0.94; 1.01)	.16
Model 4	0.97 (0.93; 1.01)	.13
Muesli		
Model 1	0.76 (0.74; 0.78)	<.001
Model 2	0.87 (0.84; 0.89)	<.001
Model 3	0.87 (0.84; 0.90)	<.001
Model 4	0.84 (0.81; 0.87)	<.001
Oat cereals		
Model 1	0.99 (0.96; 1.01)	.27
Model 2	1.06 (1.03; 1.09)	<.001
Model 3	1.12 (1.09; 1.15)	<.001
Model 4	1.11 (1.07; 1.14)	<.001

* Model 1 is the crude model; model 2 after adjusted for age, gender, marital status, education level, SEIFA alcohol drinking, smoking and physical activity level and model 1; model 3 adjusted for BMI and model 2; model 4 adjusted for fruit, vegetable, red meat, and processed meat consumption and model 3.

Supplementary Table 4
Longitudinal association between breakfast cereals consumption and heart disease by age groups*

Heart disease	Age groups					
	45–64 y		65–80 y		80 y or above	
	OR (95% CI)	*P* value	OR (95% CI)	*P* value	OR (95% CI)	*P* value
Any breakfast cereal						
Model 1	0.85 (0.79; 0.80)	<.001	0.98 (0.93; 1.03)	.43	0.98 (0.88; 1.09)	.75
Model 2	0.82 (0.77; 0.88)	<.001	0.96 (0.90; 1.01)	.14	0.88 (0.79; 0.99)	.04
Model 3	0.83 (0.77; 0.90)	<.001	0.97 (0.91; 1.04)	.40	0.91 (0.80; 1.03)	.14
Model 4	0.86 (0.80; 0.93)	<.001	1.00 (0.94; 1.08)	.89	0.93 (0.81; 1.07)	.33
Biscuit cereals						
Model 1	0.68 (0.63; 0.73)	<.001	0.77 (0.73; 0.81)	<.001	0.72 (0.67; 0.78)	<.001
Model 2	0.68 (0.63; 0.73)	<.001	0.75 (0.72; 0.79)	<.001	0.73 (0.67; 0.79)	<.001
Model 3	0.69 (0.64; 0.75)	<.001	0.75 (0.71; 0.80)	<.001	0.72 (0.66; 0.79)	<.001
Model 4	0.73 (0.67; 0.79)	<.001	0.79 (0.74; 0.84)	<.001	0.76 (0.69; 0.83)	<.001
Bran cereals						
Model 1	0.63 (0.57; 0.69)	<.001	0.62 (0.58; 0.66)	<.001	0.67 (0.61; 0.73)	<.001
Model 2	0.71 (0.65; 0.78)	<.001	0.66 (0.62; 0.71)	<.001	0.68 (0.61; 0.76)	<.001
Model 3	0.68 (0.62; 0.76)	<.001	0.65 (0.60; 0.70)	<.001	0.68 (0.60; 0.76)	<.001
Model 4	0.75 (0.68; 0.84)	<.001	0.70 (0.64; 0.75)	<.001	0.70 (0.62; 0.79)	<.001
Muesli						
Model 1	0.67 (0.63; 0.72)	<.001	0.69 (0.65; 0.72)	<.001	0.72 (0.67; 0.79)	<.001
Model 2	0.73 (0.68; 0.78)	<.001	0.73 (0.69; 0.77)	<.001	0.73 (0.66; 0.80)	<.001
Model 3	0.76 (0.70; 0.82)	<.001	0.75 (0.71; 0.80)	<.001	0.75 (0.68; 0.83)	<.001
Model 4	0.80 (0.74; 0.87)	<.001	0.78 (0.73; 0.83)	<.001	0.74 (0.66; 0.82)	<.001
Oat cereals						
Model 1	0.65 (0.61; 0.70)	<.001	0.66 (0.63; 0.70)	<.001	0.72 (0.67; 0.78)	<.001
Model 2	0.75 (0.70; 0.81)	<.001	0.73 (0.69; 0.77)	<.001	0.73 (0.68; 0.79)	<.001
Model 3	0.81 (0.74; 0.88)	<.001	0.75 (0.71; 0.79)	<.001	0.72 (0.66; 0.79)	<.001
Model 4	0.81 (0.75; 0.89)	<.001	0.77 (0.73; 0.82)	<.001	0.73 (0.66; 0.80)	<.001

* Model 1 is the crude model; model 2 after adjusted for gender, marital status, education level, SEIFA, alcohol drinking, smoking and physical activity levels; model 3 adjusted for BMI and model 2; model 4 adjusted for fruit, vegetable, red meat, and processed meat consumption and model 3.

Supplementary Table 5
Longitudinal association between breakfast cereals consumption and stroke by age groups*

Stroke	Age groups					
	45–64 y		65–80 y		80 y or above	
	OR (95% CI)	*P* Value	OR (95% CI)	*P* Value	OR (95% CI)	*P* Value
Any breakfast cereal						
Model 1	0.77 (0.66; 0.90)	.001	0.92 (0.82; 1.04)	.20	0.92 (0.76; 1.12)	.40
Model 2	0.77 (0.65; 0.91)	.002	0.89 (0.79; 1.01)	.08	0.89 (0.72; 1.10)	.27
Model 3	0.79 (0.66; 0.94)	<.01	0.91 (0.79; 1.04)	.18	0.88 (0.70; 1.11)	.29
Model 4	0.82 (0.68; 0.99)	.04	0.91 (0.78; 1.05)	.19	0.89 (0.69; 1.15)	.38
Biscuit cereals						
Model 1	0.75 (0.64; 0.88)	<.001	0.80 (0.72; 0.89)	<.001	0.84 (0.74; 0.97)	.02
Model 2	0.75 (0.63; 0.88)	.001	0.79 (0.71; 0.88)	<.001	0.82 (0.71; 0.95)	<.01
Model 3	0.74 (0.61; 0.89)	.001	0.76 (0.67; 0.86)	<.001	0.85 (0.72; 0.99)	.04
Model 4	0.82 (0.68; 1.00)	.05	0.79 (0.69; 0.89)	<.001	0.93 (0.78; 1.11)	.45
Bran cereals						
Model 1	0.56 (0.45; 0.70)	<.001	0.64 (0.56; 0.74)	<.001	0.60 (0.50; 0.73)	<.001
Model 2	0.61 (0.48; 0.78)	<.001	0.67 (0.58; 0.78)	<.001	0.62 (0.51; 0.76)	<.001
Model 3	0.59 (0.45; 0.77)	<.001	0.69 (0.59; 0.81)	<.001	0.64 (0.51; 0.80)	<.001
Model 4	0.68 (0.52; 0.90)	<.01	0.74 (0.62; 0.88)	.001	0.65 (0.51; 0.83)	.001
Muesli						
Model 1	0.54 (0.45; 0.63)	<.001	0.57 (0.51; 0.64)	<.001	0.63 (0.54; 0.75)	<.001
Model 2	0.61 (0.51; 0.73)	<.001	0.63 (0.55; 0.71)	<.001	0.70 (0.59; 0.84)	<.001
Model 3	0.64 (0.52; 0.78)	<.001	0.64 (0.56; 0.74)	<.001	0.70 (0.58; 0.86)	<.001
Model 4	0.70 (0.57; 0.86)	.001	0.68 (0.58; 0.78)	<.001	0.71 (0.57; 0.88)	.002
Oat cereals						
Model 1	0.60 (0.50; 0.71)	<.001	0.60 (0.54; 0.67)	<.001	0.61 (0.53; 0.71)	<.001
Model 2	0.68 (0.57; 0.82)	<.001	0.64 (0.57; 0.72)	<.001	0.60 (0.51; 0.70)	<.001
Model 3	0.72 (0.60; 0.88)	.001	0.67 (0.59; 0.76)	<.001	0.56 (0.46; 0.65)	<.001
Model 4	0.71 (0.57; 0.87)	.001	0.70 (0.61; 0.80)	<.001	0.57 (0.47; 0.69)	<.001

* Model 1 is the crude model; model 2 after adjusted for gender, marital status, education level, SEIFA, alcohol drinking, smoking and physical activity levels; model 3 adjusted for BMI and model 2; model 4 adjusted for fruit, vegetable, red meat and processed meat consumption and model 3.

Supplementary Table 6
Longitudinal association between breakfast cereals consumption and diabetes by age groups*

Diabetes	Age groups					
	45–64 y		65–80 y		80 y or above	
	OR (95% CI)	*P* Value	OR (95% CI)	*P* Value	OR (95% CI)	*P* Value
Any breakfast cereal						
Model 1	0.85 (0.79; 0.91)	<.001	0.85 (0.79; 0.91)	<.001	0.95 (0.81; 1.11)	.49
Model 2	0.84 (0.77; 0.90)	<.001	0.81 (0.75; 0.87)	<.001	0.87 (0.74; 1.03)	.11
Model 3	0.89 (0.82; 0.97)	.01	0.88 (0.81; 0.95)	.002	0.97 (0.80; 1.17)	.75
Model 4	0.89 (0.82; 0.98)	<.02	0.90 (0.83; 0.98)	<.02	1.00 (0.81; 1.24)	.98
Biscuit cereals						
Model 1	0.76 (0.70; 0.82)	<.001	0.83 (0.78; 0.88)	<.001	0.89 (0.80; 0.99)	.03
Model 2	0.73 (0.67; 0.79)	<.001	0.78 (0.74; 0.83)	<.001	0.85 (0.76; 0.95)	<.01
Model 3	0.73 (0.67; 0.79)	<.001	0.77 (0.71; 0.82)	<.001	0.81 (0.71; 0.92)	<.01
Model 4	0.77 (0.70; 0.84)	<.001	0.80 (0.74; 0.86)	<.001	0.82 (0.71; 0.94)	<.01
Bran cereals						
Model 1	0.63 (0.57; 0.70)	<.001	0.63 (0.58; 0.69)	<.001	0.59 (0.51; 0.69)	<.001
Model 2	0.68 (0.61; 0.76)	<.001	0.67 (0.62; 0.73)	<.001	0.58 (0.50; 0.69)	<.001
Model 3	0.66 (0.59; 0.74)	<.001	0.68 (0.62; 0.75)	<.001	0.55 (0.46; 0.67)	<.001
Model 4	0.71 (0.63; 0.81)	<.001	0.74 (0.67; 0.82)	<.001	0.58 (0.48; 0.71)	<.001
Muesli						
Model 1	0.45 (0.41; 0.49)	<.001	0.47 (0.44; 0.50)	<.001	0.58 (0.61; 0.66)	<.001
Model 2	0.53 (0.49; 0.58)	<.001	0.53 (0.49; 0.57)	<.001	0.66 (0.57; 0.76)	<.001
Model 3	0.61 (0.56; 0.67)	<.001	0.57 (0.52; 0.62)	<.001	0.69 (0.59; 0.81)	<.001
Model 4	0.62 (0.56; 0.69)	<.001	0.58 (0.53; 0.64)	<.001	0.72 (0.60; 0.86)	<.001
Oat cereals						
Model 1	0.71 (0.65; 0.76)	<.001	0.72 (0.68; 0.77)	<.001	0.77 (0.69; 0.85)	<.001
Model 2	0.76 (0.70; 0.82)	<.001	0.74 (0.69; 0.79)	<.001	0.75 (0.67; 0.84)	<.001
Model 3	0.84 (0.77; 0.92)	<.001	0.83 (0.77; 0.89)	<.001	0.81 (0.72; 0.92)	.002
Model 4	0.84 (0.76; 0.92)	<.001	0.85 (0.79; 0.92)	<.001	0.85 (0.74; 0.98)	.03

* Model 1 is the crude model; model 2 after adjusted for gender, marital status, education level, SEIFA, alcohol drinking, smoking and physical activity levels; model 3 adjusted for BMI and model 2; model 4 adjusted for fruit, vegetable, red meat, and processed meat consumption and model 3.

Supplementary Table 7
Cereals consumption by two survey points for new diagnoses

Diseases	Baseline	Follow-up	*P* for trend*
	N (%)		
Heart diseases			
(n = 14,148 with 28,296 observations)	—	—	—
Any breakfast cereal	11,414 (86.3%)	11,385 (85.0%)	<.001
Biscuit cereals	4494 (31.8%)	2583 (17.9%)	<.001
Bran cereals	2812 (19.9%)	1274 (9%)	<.001
Muesli	3865 (27.3%)	2528 (17.9%)	<.001
Oat cereals	4385 (31.0%)	2580 (18.2%)	<.001
Stroke			
(n = 2911 with 5822 observations)	—	—	—
Any breakfast cereal	2300 (85.6%)	2299 (85.3%)	.99
Biscuit cereals	964 (33.2%)	558 (19.2%)	<.001
Bran cereals	552 (19.0%)	253 (8.7%)	<.001
Muesli	688 (23.6%)	409 (14.1%)	<.001
Oat cereals	889 (30.6%)	505 (17.4%)	<.001
Diabetes			
(n = 5383 with 10,766 observations)	—	—	—
Any breakfast cereal	4000 (81.6%)	4174 (82.3%)	.19
Biscuit cereals	1656 (30.8%)	1006 (18.7%)	<.001
Bran cereals	974 (18.1%)	511 (9.5%)	<.001
Muesli	1100 (20.4%)	727 (13.5%)	<.001
Oat cereals	1500 (27.9%)	992 (18.4%)	<.001

GEE = generalized estimating equation.
* GEE was used to examine the association between different types of cereals consumption and survey points.