



## Wholegrain and legume consumption and the 5-year incidence of age-related cataract in the Blue Mountains Eye Study

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### Abstract

The present study aims to investigate the effect of wholegrain and legume consumption on the incidence of age-related cataract in an older Australian population-based cohort. The Blue Mountains Eye Study (BMES) is a population-based cohort study of eye diseases among older adults aged 49 years or older (1992–1994, *n* 3654). Of 2334 participants of the second examination of the BMES (BMES 2, 1997–2000), 1541 (78.3 % of survivors) were examined 5 years later (BMES 3) who had wholegrain and legume consumption estimated from the FFQ at BMES 2. Cataract was assessed using photographs taken during examinations following the Wisconsin cataract grading system. Multivariable-adjusted logistic regression models were used to assess associations with the 5-year incidence of cataract from BMES 2 (baseline) to BMES 3. The 5-year incidence of cortical, nuclear and posterior subcapsular (PSC) cataract was 18.2, 16.5 and 5.9 %, respectively. After adjustment for age, sex and other factors, total wholegrain consumption at baseline was not associated with incidence of any type of cataract. High consumption of legumes showed a protective association for incident PSC cataract (5th quintile: adjusted OR 0.37; 95 % CI 0.15, 0.92). There was no significant trend of this association across quintiles (*P* = 0.08). In this older Australian population, we found no associations between wholegrain intake at baseline and the 5-year incidence of three cataract types. However, intake of legumes in the highest quintile, compared with the lowest quintile, may protect against PSC formation, a finding needing replication in other studies.

**Key words:** Age-related cataracts: Whole grains: Legumes: Epidemiology

Age-related cataract is the opacification of the eye lens occurring from the age of 50 years onwards<sup>(1,2)</sup> and remains a major cause of vision impairment worldwide<sup>(3)</sup>. There are three types of age-related cataract, each affecting a different part of the lens: cortical, nuclear and posterior subcapsular (PSC) cataract<sup>(1,2)</sup>. Strategies to delay development and slow progression of age-related cataract would reduce eye health care cost and the burden on affected persons and their families. Nutritional and dietary modification is an attractive preventive strategy from a public health standpoint. As such, there has been much interest in dietary factors that may affect cataractogenesis. While individual nutrients have shown some beneficial effect on cataract formation<sup>(4–7)</sup>, individual nutrients are rarely consumed in

isolation. Moreover, nutrient supplements have not shown the same benefits in clinical trials as that observed in observational studies<sup>(8)</sup>. It may be more beneficial and practical to investigate key components of the diet, rather than individual nutrients, to further elucidate the benefit of diet on eye and systemic health.

Both whole grains and legumes are slow-release carbohydrates, rich in fibre, good sources of antioxidants and have a lower glycaemic index (GI)<sup>(9–11)</sup>. Higher intakes of whole grains have been shown to have beneficial effects for diabetes, CVD, obesity and mortality<sup>(12–14)</sup>. Similarly, legume consumption has also been shown to be associated with lower risks of CVD<sup>(15)</sup>, diabetes<sup>(16)</sup> and mortality<sup>(17)</sup>. However, there is limited

**Abbreviations:** BMES, Blue Mountains Eye Study; GI, glycaemic index; PSC, posterior subcapsular.

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information on the association between wholegrain and legume consumption and the risk of age-related cataract.

Due to the high nutritional content and antioxidant properties of whole grains and legumes, we speculate that high consumption of whole grains and/or legumes by older people may have protective effects on the eye and/or ageing, as nuclear cataract is considered an ageing marker. In this report, we aimed to investigate the longitudinal associations between wholegrain and legume consumption at baseline and the 5-year incidence of age-related cataract in an older Australian cohort sample, the Blue Mountains Eye Study (BMES) population.

## Methods

### Study population

The BMES is an observational, population-based cohort study of vision and common eye diseases in a population aged 49 years and older, living in the Blue Mountains region, west of Sydney, Australia. The baseline examinations (BMES 1, 1992–1994) were conducted on 3654 participants (82.4% of eligible). Five years later (1997–1999, BMES 2), 2334 (75.1% of survivors) participants were re-examined and 1952 (76.6% of survivors) participants were followed 10 (2002–2004, BMES 3) years later. For this report, the BMES 2 population serves as the baseline of this cohort, where both wholegrain and legume consumption information was available, and the 5-year incidence of cataract was assessed using lens photographs taken at BMES 2 and BMES 3 examinations.

### Examination procedures

Detailed examination procedures have been described previously<sup>(18)</sup>. The same procedures were conducted for all examinations. Briefly, after pupil dilation, each participant underwent a detailed eye examination, including lens photography. Interviewer-administered questionnaires were used to collect demographic, dietary data and medical information. Written, informed consent was obtained from each participant. The study adhered to the tenets of the Declaration of Helsinki and was approved by the Human Ethics Committees of the University of Sydney and the Western Sydney Area Health Service.

### Cataract grading

Lens photographic and cataract grading procedures have been described in detail previously<sup>(18)</sup>. In brief, lens photographs taken during eye examinations were assessed for cataract in a masked manner following the Wisconsin cataract grading system<sup>(19)</sup>. Retroillumination (Neitz CT-R; Neitz Instruments) and slit lamp (Topcon SL-7 E, Topcon Optical Co.) lens photographs taken during the eye examinations were used to assess cataract. Cortical and PSC cataract were assessed using a grid overlay to allow estimation of the percentage area of involvement for each type of cataract. Cortical cataract was defined as  $\geq 5\%$  of total area involved. PSC cataract was defined as any such

opacity present. Nuclear cataract was assessed by comparing the slit lamp photograph to a set of four standard photographs and was defined as nuclear opacity greater than standard photograph no. 3. Inter- and intragrader reliability of the cataract grading have been reported previously<sup>(20)</sup>.

A participant without a particular type of cataract in any eye at baseline was considered at risk of developing that particular type of cataract in the follow-up and was included in the assessment of incidence of this cataract type. For example, if a participant had nuclear cataract only at baseline, they would be considered at risk of developing both cortical and PSC cataract at follow-up.

### Dietary assessment

Participants were also asked to complete a 145-item semi-quantitative FFQ to assess typical food consumption over the past year. The FFQ was a modified Willett FFQ<sup>(21)</sup> for the Australian diet and vernacular and included portion size estimates and frequency. Brand details of breakfast cereals were also collected. Consumption frequency was measured using nine categories from 0 to 4 serves/d. Responses to each FFQ item were then converted to daily intake. Daily nutrient intakes were estimated using purpose-built software incorporating the Australian Tables of Food Composition (NUTTAB95)<sup>(22)</sup>. Validation of the FFQ was conducted in a subsample of the population ( $n$  78) and compared against the average of three, 4-d weighed food records over 12 months<sup>(21)</sup>.

We estimated wholegrain consumption frequency and daily intake from four items in the FFQ: breakfast cereal, oatmeal, wholemeal/multigrain breads and brown rice. Estimates of wholegrain intakes in g/d were calculated by multiplying the wholegrain percentage of each wholegrain food, the weight per serve of wholegrain food, determined from NUTTAB95<sup>(22)</sup>, and the number of serves/d indicated in the FFQ. Wholegrain percentage of breakfast cereal items was based on nutritional information available from the food company or manufacturers' website or estimated from similar breakfast cereals in the absence of manufacturer information as determined by the study dietitian (V. M. F.). Wholegrain percentage of oatmeal, wholemeal/multigrain breads and brown rice items was based on values reported in The Grains & Legumes Health Report<sup>(23)</sup>.

Legume consumption was determined using three items from the FFQ: baked beans, soyabeans, and other beans and lentils. Estimates of legume intake in g/d were calculated by multiplying the weight per serve of legumes, determined from NUTTAB95<sup>(22)</sup>, by the number of serves/d indicated in the FFQ.

Wholegrain, legume and other nutrient intakes were energy-adjusted following the residual method described by Willett & Stampfer<sup>(24)</sup>. Total diet score was developed for BMES<sup>(25)</sup> to assess adherence to Australian dietary guidelines with higher scores indicating higher adherence to dietary recommendations. One serve of wholegrain food is estimated as having 8 g wholegrain intake, in line with Australian dietary guidelines<sup>(26,27)</sup>, where six serves are equivalent to the daily target intake of 48 g whole grains. One serve of legume food is estimated as having 75 g legume intake, also in line with Australian dietary guidelines<sup>(27,28)</sup>.



### Statistical analysis

All analyses were conducted using SAS 9.4 (SAS Institute). Baseline characteristics were compared for BMES 2 participants who did and did not attend the follow-up examination 5 years later (Table 1). Differences in baseline characteristics were tested using independent *t* test for continuous variables (mean values and standard deviations) and Pearson's  $\chi^2$  test for categorical variables (frequencies in percentages). Quintiles of wholegrain and legume intake were created with the lowest quintile as the reference group. Characteristics of participants attending the follow-up visits were compared across quintiles of wholegrain and legume consumption (Table 2). Differences across quintiles were tested using Mantel-Haenszel  $\chi^2$  test.

Potential confounding variables at baseline of this report (BMES 2) included age, sex, smoking status (past, current and never smokers), hypertension (defined as systolic blood pressure  $\geq 160$  mmHg, diastolic blood pressure  $\geq 100$  mmHg, self-reported hypertension or use of antihypertensive medications), diabetes (defined as fasting blood glucose  $\geq 7.0$  mmol/l or self-reported diabetes or use of diabetic medication), education (attainment of trade certificate or higher degree), self-reported use of inhaled or oral steroids and the presence of myopia (spherical equivalent of  $< -1.0$  dioptre). The following potential confounding nutritional variables associated with the exposures or the outcomes were also considered: total diet score, energy-adjusted fibre, vitamin C, vitamin E, Zn, lutein, zeaxanthin and beta-carotene. Because different cataract types may be associated with different risk factors, the final parsimonious models varied for each cataract type and only included variables that were significantly ( $P < 0.05$ ) associated with that particular cataract type, as determined by stepwise regression process.

Multivariable-adjusted logistic regression models were used to assess the associations between baseline (at BMES 2) wholegrain and legume consumption (by quintiles and per serve/d increase) and 5-year cataract incidence. OR and 95 % CI are presented.  $P_{\text{for trend}}$  was calculated using the median trend method. Statistical significance was set at  $P < 0.05$ .

### Results

Of the 2334 participants in BMES 2, 1722 (87.4 % of survivors) returned for the BMES 3 examinations. Those who participated in BMES 2 but not BMES 3 were older, more likely to be male, a current smoker or have greater pack/years smoked, a history of hypertension, have prevalent cortical and nuclear cataract and lower consumption of whole grains and vitamin E but less likely to have higher education than those who did participate in the BMES 3 examinations (Table 1).

Of the 1722 participants, 1541 (89.5 %) had usable FFQ with estimated wholegrain and legume consumption. The mean intake of whole grains in this population was 49.6 (SD 34.8) g/d, with 49.2 % of the population consuming the recommended daily target intake of 48 g. The mean legume intake was 18.5 (SD 29.9) g/d. Table 2 presents the baseline characteristics of the entire BMES 2 population by quintiles of energy-adjusted wholegrain and legume consumption. Participants with higher intakes of whole grains were less likely to be current smokers or have less pack/years smoked, also less likely to have hypertension and high BMI, but more likely to have higher education and higher dietary fibre and vitamin E intake (Table 2). Participants with higher intakes of legumes were younger, more likely to be female, to have hypertension and higher dietary fibre intake

**Table 1.** Comparison of characteristics of the Blue Mountains Eye Study 2 participants and non-participants of the follow-up examination 5 years later\* (Mean values and standard deviations; numbers and percentages)

Baseline characteristics	Participants (n 1722)			Non-participants (n 612)			P†
	Mean	%	SD	Mean	%	SD	
Age (years)	68.0		7.8	74.2		9.5	<0.001‡
Female		59.1			53.1		<0.001‡
Non-smoker		52.0			44.9		<0.001‡
Past-smoker		40.2			42.9		
Current smoker		7.8			12.2		
Pack/years of smoking	12.4		23.3	16.6		28.3	0.001‡
Hypertension		51.7			59.1		0.002‡
Diabetes		10.0			12.8		0.06
Education§		62.5			54.4		<0.001‡
Myopia		14.6			17.1		0.16
Inhaled steroids		15.0			14.8		0.91
Cortical cataract		24.2			36.0		<0.001‡
Nuclear cataract		26.8			44.6		<0.001‡
Posterior subcapsular cataract		5.5			7.7		0.08
Daily energy intake (kJ)	8544.9		2408.3	8581.3		2634.1	0.79
Dietary fibre (g/d)	28.3		10.8	28.1		11.6	0.81
Vitamin E (mg)	9.5		7.8	8.3		6.2	0.001‡
Wholegrain consumption (g/d)	49.6		34.8	44.2		34.5	0.004‡
Legume consumption (g/d)	18.5		29.9	19.4		29.3	0.56

\* Continuous variables shown as mean values and standard deviations and categorical variables shown as percentages.

† *P* values based on *t* tests for means and  $\chi^2$  for frequencies.

‡ Statistically significant differences ( $P < 0.05$ ).

§ Education defined as trade certificate or higher qualification.

**Table 2.** Characteristics according to quintiles of energy-adjusted wholegrain and legume consumption in the Blue Mountains Eye Study (BMES) 2 population\* (Mean values and standard deviations; numbers and percentages)

Characteristics	Wholegrain consumption (range g/d)															Pt
	Quintile 1 (<15.7)			Quintile 2 (15.7–33.8)			Quintile 3 (33.9–50.2)			Quintile 4 (50.3–69.9)			Quintile 5 (≥70.0)			
	Mean	%	SD	Mean	%	SD	Mean	%	SD	Mean	%	SD	Mean	%	SD	
<i>n</i>	287			295			323			329			307			
Age (years)	67.4		7.6	67.5		7.4	67.5		7.2	68.5		7.3	67.9		8.2	0.30
Female		49.1			63.7			61.3			62.6			58.6		0.05
Non-smoker		42.9			48.3			52.8			55.2			61.6		<0.001‡
Past-smoker		42.8			42.8			40.7			38.7			36.5		
Current smoker		14.3			8.9			6.5			6.1			2.0		
Pack/years of smoking	18.8		24.7	13.9		22.4	10.8		19.1	9.8		18.4	7.7		16.7	<0.001‡
Hypertension		54.9			54.1			52.3			49.2			46.6		0.02‡
Diabetes		12.9			9.5			7.4			11.3			9.8		0.45
Education§		53.8			60.1			65.7			64.9			70.5		<0.001‡
Myopia		13.2			11.9			14.6			15.2			15.6		0.20
Inhaled steroids		14.0			16.6			15.0			18.3			13.4		0.93
BMI (kg/m <sup>2</sup> )	27.9		4.7	27.7		4.8	28.0		4.5	27.2		4.7	26.8		4.0	0.005‡
Daily energy intake (kJ)	9050.1		2770.6	8187.8		2567.8	8104.5		2191.5	8495.9		2085.0	8931.6		2290.6	<0.001‡
Daily dietary intake (g)																
Fibre	21.6		6.9	25.1		6.8	27.9		7.0	30.3		8.0	33.5		8.2	<0.001‡
Lutein/zeaxanthin (µg)	775.1		458.5	891.8		487.2	935.1		462.2	997.3		549.6	930.4		519.0	<0.001‡
Vitamin E (mg)	6.5		2.6	7.7		2.8	8.1		4.3	8.9		5.8	16.1		13.4	<0.001‡
Vegetables	416.1		155.4	441.3		156.6	450.5		145.7	467.3		177.2	444.0		181.0	0.004‡
Fruits	285.5		227.7	331.9		224.6	369.8		223.1	369.6		212.1	361.9		199.6	<0.001‡
Breads/cereals/rice/pasta	130.7		71.8	165.3		87.8	212.7		78.9	248.7		87.7	318.2		112.5	<0.001‡
Dairy products	329.2		259.3	360.6		214.0	377.9		248.0	378.7		231.4	359.4		226.0	0.07
Meats	152.6		73.7	143.3		58.5	137.5		58.4	130.7		62.7	113.1		57.7	<0.001‡
Eggs	22.4		20.1	22.8		20.4	18.7		17.0	19.5		17.1	15.6		13.7	<0.001‡
Fish	26.9		36.3	34.1		28.8	31.2		27.6	34.1		29.9	31.3		30.8	0.03‡
Nuts	7.4		13.8	8.5		12.7	7.4		9.7	6.8		9.3	8.7		11.8	0.17
Fats	17.6		10.1	16.1		9.2	16.2		9.6	15.5		9.3	15.2		10.5	0.02‡
Biscuits/cakes	45.9		39.4	45.1		32.5	45.2		34.2	44.1		36.2	37.6		29.8	0.02‡
Total diet score	8.1		2.1	9.1		2.0	9.5		2.1	10.2		1.9	10.6		2.1	<0.001‡

Whole grains, legumes and incident cataract

Characteristics	Legume consumption (range g/d)															Pt
	Quintile 1 (<3.6)			Quintile 2 (3.6–8.6)			Quintile 3 (8.6–13.7)			Quintile 4 (13.7–24.6)			Quintile 5 (>24.6)			
	Mean	%	SD	Mean	%	SD	Mean	%	SD	Mean	%	SD	Mean	%	SD	
<i>n</i>	303			312			322			303			301			
Age (years)	69.0		7.7	68.7		7.3	67.2		7.9	66.5		7.3	67.5		7.3	<0.001‡
Female		51.2			60.6			61.2			62.1			61.1		0.02‡
Non-smoker		53.8			53.53			50.9			53.5			50.0		0.46
Past-smoker		40.3			39.1			39.1			39.2			43.7		
Current smoker		5.9			7.4			10.0			7.3			6.3		
Pack/years of smoking	11.0		20.6	11.9		20.4	12.2		20.1	12.5		20.8	12.7		21.6	0.86

Table 2. (Continued)

	Legume consumption (range g/d)															P†
	Quintile 1 (<3.6)			Quintile 2 (3.6–8.6)			Quintile 3 (8.6–13.7)			Quintile 4 (13.7–24.6)			Quintile 5 (>24.6)			
	Mean	%	SD	Mean	%	SD	Mean	%	SD	Mean	%	SD	Mean	%	SD	
Hypertension		45.0		53.2			52.5			49.3			56.5			0.04‡
Diabetes		9.2		10.0			11.5			8.6			11.3			0.62
Education§		65.8		61.2			65.0			60.2			63.7			0.56
Myopia		12.9		15.1			16.5			11.9			14.3			0.96
Inhaled steroids		14.3		16.3			13.8			17.5			15.8			0.54
BMI (kg/m <sup>2</sup> )	27.1		3.8	27.5		4.6	28.1		4.6	27.4		4.8	27.5		4.8	0.11
Daily energy intake (kJ)	10 296.7		2063.6	8078.2		2069.4	8011.6		2226.4	7723.9		1891.4	8662.0		2795.7	<0.001‡
Daily dietary intake (g)¶																
Fibre	26.1		9.5	26.3		6.7	26.6		7.2	28.0		7.5	32.4		9.5	<0.001‡
Lutein/zeaxanthin (µg)	826.3		503.4	871.4		433.7	894.9		449.9	873.7		425.1	1083.7		636.7	<0.001‡
Vitamin E (mg)	10.3		10.1	9.1		6.7	9.1		6.5	9.5		7.3	9.4		7.9	0.28
Vegetables	401.9		161.6	426.8		148.6	421.4		135.6	440.3		139.8	535.5		198.4	<0.001‡
Fruits	318.4		235.0	328.8		214.7	330.5		200.6	347.6		198.3	402.7		238.2	<0.001‡
Breads/cereals/rice/pasta	196.6		111.1	211.0		97.8	212.6		95.8	223.1		105.0	242.6		131.8	<0.001‡
Dairy products	363.1		269.8	361.2		231.3	368.5		232.4	352.6		211.5	364.3		235.6	0.95
Meats	140.9		72.5	141.8		59.4	139.1		59.4	133.3		54.2	120.0		67.0	<0.001‡
Eggs	17.8		19.2	18.4		16.0	21.2		18.8	20.3		16.8	20.9		18.5	0.06
Fish	25.1		31.3	26.8		21.8	29.8		24.7	33.5		28.4	43.0		41.4	<0.001‡
Nuts	7.4		14.1	7.2		10.3	8.1		11.9	7.4		7.7	8.6		12.5	0.53
Fats	17.3		10.0	17.5		9.6	16.1		10.0	15.7		9.3	13.8		9.4	<0.001‡
Biscuits/cakes	45.6		45.4	42.6		25.8	46.4		33.9	44.8		29.3	38.2		35.5	0.03‡
Total diet score	9.0		2.1	9.2		2.0	9.4		2.1	9.7		2.2	10.4		2.2‡	<0.001‡

\* For 1541 participants who attended the BMES 2 and BMES 3 examinations and who had completed the FFQ at BMES 2.

† P values for trend calculated using Mantel–Haenszel  $\chi^2$  test or the F test accordingly.

‡ Significant trend of association ( $P_{\text{for trend}} < 0.05$ )

§ Education defined as trade certificate or higher qualification

¶ Energy-adjusted dietary variables, in g unless otherwise specified.

(Table 2). Overall, wholegrain and legume consumptions were positively associated with consumptions of majority of healthy foods and high adherence to dietary guidelines (total diet score) in this population, with significant *P* values for trend across quintiles of wholegrain and legume consumptions (Table 2). However, correlations between consumptions of whole grains or legumes and these food groups were low ( $r < 0.3$ ), except for the correlation between consumptions of whole grains and breads/cereals/rice/pasta ( $r = 0.6$ ). Baseline characteristics by quintiles of energy-adjusted wholegrain and legume consumption of BMES 2 participants at-risk of different types of cataract did not differ much from the entire population (online Supplementary Table S1).

After excluding those with cataract at the BMES 2 examination, there were 852, 522 and 1011 participants at risk of incident cortical, nuclear and PSC cataract, respectively. The 5-year incidence of cortical, nuclear and PSC cataract was 18.2, 16.5 and 5.9%, respectively.

After multivariable adjustment, there were no significant associations between total wholegrain consumption and any type of incident cataract (Table 3). Further analysis using different sources of whole grain also showed no significant associations between consumption of any main source of whole grain and incidence of any type of cataract (Table 4).

The associations between legume consumption and incidence of the three cataract types are shown in Table 5. A protective association between the highest quintile consumption of legumes and incident PSC cataract was observed, compared with the lowest quintile (adjusted OR for Q5 *v.* Q1, 0.37, 95% CI 0.15, 0.92) after adjustment for age, sex, smoking status, education, inhaled steroid use and myopia. However, there was no significant trend of this association across the quintiles ( $P = 0.08$ ) (Table 5). No associations were observed between legume consumption and incidence of cortical or nuclear cataract (Table 5).

Findings were essentially the same when further adjustment for daily energy intake (as a continuous variable or as quintiles) in the logistic models in a supplementary analysis (data not shown).

## Discussion

In this population-based sample of older Australians, we found no association between wholegrain consumption at baseline and 5-year incidence of any of the three types of cataract. However, a protective association for incident PSC cataract was found among those in the highest quintile of legume consumption compared with those in the lowest quintile.

Whole grains are slow-release carbohydrates with strong antioxidant activity and a good source of vitamins and minerals<sup>(10,29)</sup>. Wholegrain consumption has been linked with reduced risk of many chronic diseases such as CHD, stroke and diabetes<sup>(12-14)</sup>. Age-related cataract also involves chronic processes of progressive degeneration of lens proteins, closely linked with ageing process, resulting in loss of lens transparency<sup>(1)</sup>. Moreover, all these chronic diseases, including age-related cataract, have been linked to oxidative processes and inflammation that accumulate over time<sup>(30,31)</sup>. Given the high nutritional content and antioxidant property of whole grains<sup>(10,29)</sup>, and that cataractogenesis involves oxidation processes<sup>(32,33)</sup>, we speculated that high consumption of whole grain in daily diet may benefit overall health including the eye and ageing process.

Previous cross-sectional and longitudinal studies that investigated the association between whole grains and cataract were mainly conducted in women. In the Harvard Nurses' Health Study, those who had high consumption of whole grains were less likely to have nuclear opacities than those with low consumption, although the difference was not statistically significant<sup>(34)</sup>. Low diet quality, including low intake of grains, was related to higher prevalence of nuclear cataract in an ancillary study of the Women's Health Initiative<sup>(35)</sup>. Whole grains were a main contributor (17%) to the total antioxidant capacity in diet, and increasing total antioxidant capacity was found associated with decreased risk of incident cataract in a cohort of women<sup>(36)</sup>. There has been no other study reporting on the longitudinal associations between whole grains and age-related cataract in other general populations. In the present study of our BMES cohort, we did not observe longitudinal associations

**Table 3.** Association between energy-adjusted total wholegrain consumption and 5-year incidence of cortical, nuclear and posterior subcapsular (PSC) cataract in the Blue Mountains Eye Study (BMES) (Numbers and percentages; odds ratios and 95% confidence intervals)

Wholegrain consumption	Cortical cataract				Nuclear cataract				PSC cataract			
	<i>n/N</i>	%	Adjusted OR*	95% CI	<i>n/N</i>	%	Adjusted OR†	95% CI	<i>n/N</i>	%	Adjusted OR‡	95% CI
Quintile 1	30/167	18.0	1.0 (ref)		15/96	15.6	1.0 (ref)		11/197	5.6	1.0 (ref)	
Quintile 2	29/152	19.1	1.05	0.59, 1.87	17/96	17.7	1.08	0.47, 2.48	5/191	2.6	0.44	0.15, 1.33
Quintile 3	26/177	14.7	0.72	0.40, 1.29	17/113	15.0	0.90	0.40, 2.05	22/210	10.5	1.64	0.75, 3.61
Quintile 4	40/184	21.7	1.19	0.68, 2.01	27/118	22.9	1.24	0.56, 2.75	7/213	3.3	0.43	0.16, 1.17
Quintile 5	30/172	17.4	0.90	0.51, 1.60	10/99	10.1	0.82	0.32, 2.14	15/200	7.5	0.97	0.42, 2.26
<i>P</i> <sub>for trend</sub>			0.90				0.88				0.92	
Per 8 g serve/d increase§	155/852	18.2	0.99	0.95, 1.04	86/522	16.5	1.00	0.93, 1.08	60/1011	5.9	1.01	0.96, 1.08

*n/N*, number of cases/number at risk.

\* Parsimonious model for cortical cataract adjusted for age, sex and smoking status (past, current and never smokers) at BMES 2.

† Parsimonious model for nuclear cataract adjusted for age, sex, smoking status and energy-adjusted vitamin E intake at BMES 2.

‡ Parsimonious model for PSC cataract adjusted for age, sex, smoking status, education, inhaled steroid use and myopia at BMES 2.

§ Weight per serve estimated from wholegrain component within foods consumed.



**Table 4.** Association between energy-adjusted wholegrain consumption from different sources and 5-year incidence of cortical, nuclear and posterior subcapsular (PSC) cataract in the Blue Mountains Eye Study (BMES) (Odds ratios and 95 % confidence intervals)

Wholegrain consumption	Cortical cataract			Nuclear cataract			PSC cataract		
	Adjusted OR*	95 % CI	<i>P</i> <sub>for trend</sub>	Adjusted OR†	95 % CI	<i>P</i> <sub>for trend</sub>	Adjusted OR‡	95 % CI	<i>P</i> <sub>for trend</sub>
<b>Oatmeal</b>									
Quintile 1	1.0 (ref)		0.21	1.0 (ref)		0.81	1.0 (ref)		0.65
Quintile 2	1.15	0.66, 1.99		1.13	0.52, 2.46		1.33	0.59, 3.00	
Quintile 3	0.87	0.49, 1.54		0.70	0.31, 1.61		0.97	0.41, 2.26	
Quintile 4	1.07	0.62, 1.84		0.79	0.36, 1.72		0.54	0.21, 1.41	
Quintile 5	0.71	0.39, 1.28		0.90	0.41, 1.98		1.00	0.44, 2.30	
Per 8 g serve/d increase§	0.96	0.88, 1.05	–	0.99	0.87, 1.12	–	1.00	0.81, 1.26	–
<b>Wholemeal/multigrain bread</b>									
Quintile 1	1.0 (ref)		0.55	1.0 (ref)		0.45	1.0 (ref)		0.38
Quintile 2	1.26	0.72, 2.21		1.47	0.62, 3.52		1.08	0.43, 2.74	
Quintile 3	1.08	0.60, 1.94		1.88	0.78, 4.50		0.84	0.32, 2.24	
Quintile 4	1.03	0.58, 1.81		1.67	0.73, 3.82		1.21	0.50, 2.91	
Quintile 5	0.96	0.54, 1.70		1.57	0.68, 3.61		1.33	0.55, 3.18	
Per 8 g serve/d increase§	0.97	0.88, 1.05	–	1.06	0.94, 1.19	–	1.06	0.93, 1.20	–
<b>Breakfast cereal</b>									
Quintile 1	1.0 (ref)		0.24	1.0 (ref)		0.21	1.0 (ref)		0.75
Quintile 2	1.30	0.65, 2.58		0.83	0.35, 1.94		0.54	0.18, 1.67	
Quintile 3	1.34	0.68, 2.63		0.90	0.39, 2.09		1.34	0.55, 3.26	
Quintile 4	1.15	0.58, 2.30		0.55	0.22, 1.36		0.61	0.22, 1.68	
Quintile 5	1.62	0.83, 3.14		0.57	0.18, 1.82		0.85	0.33, 2.17	
Per 8 g serve/d increase§	1.03	0.97, 1.10	–	0.88	0.75, 1.04	–	0.93	0.83, 1.04	–
<b>Brown rice</b>									
Quintile 1	1.0 (ref)		0.46	1.0 (ref)		0.29	1.0 (ref)		0.55
Quintile 2	1.07	0.59, 1.95		1.45	0.66, 3.20		1.60	0.70, 3.67	
Quintile 3	1.14	0.62, 2.08		1.00	0.41, 2.41		0.95	0.38, 2.37	
Quintile 4	1.61	0.91, 2.84		0.69	0.28, 1.68		0.63	0.24, 1.64	
Quintile 5	0.95	0.52, 1.71		1.53	0.68, 3.48		0.89	0.38, 2.10	
Per 8 g serve/d increase§	0.91	0.72, 1.13	–	1.10	0.92, 1.31	–	1.10	0.95, 1.26	–

\* Parsimonious model for cortical cataract adjusted for age, sex and smoking status at BMES 2.

† Parsimonious model for nuclear cataract adjusted for age, sex, smoking status and energy-adjusted vitamin E intake at BMES 2.

‡ Parsimonious model for PSC cataract adjusted for age, sex, smoking status, education, inhaled steroid use and myopia at BMES 2.

§ Weight per serve estimated from wholegrain component within foods consumed.

**Table 5.** Association between energy-adjusted legume consumption and 5-year incidence of cortical, nuclear and posterior subcapsular (PSC) cataract in the Blue Mountains Eye Study (BMES) (Numbers and percentages; odds ratios and 95 % confidence intervals)

Legume consumption	Cortical cataract				Nuclear cataract				PSC cataract			
	<i>n/N</i>	%	Adjusted OR*	95 % CI	<i>n/N</i>	%	Adjusted OR†	95 % CI	<i>n/N</i>	%	Adjusted OR‡	95 % CI
Quintile 1	32/166	19.3	1.0 (ref)		17/88	19.3	1.0 (ref)		18/196	9.2	1.0 (ref)	
Quintile 2	29/175	16.6	0.80	0.45, 1.40	15/82	18.3	0.83	0.36, 1.90	10/202	5.0	0.52	0.23, 1.18
Quintile 3	36/178	20.2	1.10	0.64, 1.89	15/128	11.7	0.55	0.25, 1.24	12/211	5.7	0.62	0.28, 1.35
Quintile 4	30/176	17.1	0.90	0.51, 1.58	17/111	15.3	0.80	0.36, 1.79	13/204	6.4	0.71	0.32, 1.56
Quintile 5	28/157	17.8	0.97	0.55, 1.72	22/113	19.5	1.04	0.48, 2.24	7/198	3.5	0.37§	0.15, 0.92
<i>P</i> <sub>for trend</sub>			0.93				0.44				0.08	
Per 75 g serve/d increase	155/852	18.2	1.32	0.84, 2.07	86/522	16.5	1.13	0.60, 2.15	60/1011	5.9	1.02	0.59, 1.75

*n/N*, number of cases/number at risk.

\* Parsimonious model for cortical cataract adjusted for age, sex and smoking status at BMES 2.

† Parsimonious model for nuclear cataract adjusted for age, sex, smoking status, and energy-adjusted vitamin E intake at BMES 2.

‡ Parsimonious model for PSC cataract adjusted for age, sex, smoking status, education, inhaled steroid use and myopia at BMES 2.

§ Statistical significance (*P* < 0.05).

|| Weight per serve estimated from legume component within foods consumed.

between wholegrain consumption at baseline and the 5-year risk of developing any type of age-related cataract.

Besides the possibility of no association, the lack of longitudinal association in our study sample could also be due to

the overall low consumption level of whole grain among the BMES participants, with <50 % of the population reaching the daily target intake of 48 g. A recent report using 2011–2013 Australian Health Survey data indicated only 42.4 % of older

Australians aged  $\geq 51$  years reached the recommended whole-grain daily intake target<sup>(37)</sup>. Recent reports from the US and the UK also indicated low level of wholegrain consumption in these countries among all age groups, including older adults<sup>(38,39)</sup>.

Previous research has suggested that individual wholegrain foods may have differing effects, due to differing nutrient composition<sup>(40,41)</sup> and GI<sup>(42)</sup> of individual wholegrain foods. For example, antioxidant activity is higher in wheat (76.7  $\mu\text{mol/g}$  of grain) and oats (74.7  $\mu\text{mol/g}$  of grain) compared with brown rice (55.8  $\mu\text{mol/g}$  of grain)<sup>(43)</sup>, while average GI was higher in whole wheat bread (GI = 74) and brown rice (GI = 68) than rolled oats (GI = 55)<sup>(9)</sup>. It was speculated that different sources of whole grains may affect different types of cataract: for example, lower GI of rolled oats may be protectively associated with cortical or PSC cataract, which are most linked with diabetes and glucose levels<sup>(1)</sup>; whereas wholegrain sources with high antioxidant activity may be protectively associated with nuclear cataract<sup>(33)</sup>. However, in this older Australian population, we did not observe any association of cataract incidence with different food sources of whole grain. Again, the overall low consumption of whole grains in this population could have limited our ability to assess individual wholegrain sources.

High consumption of legumes has been linked to lower risk of diabetes<sup>(16)</sup>, CVD<sup>(10,15)</sup> and mortality<sup>(17)</sup>. We found that BMES participants in the highest quintile of legume intake, compared with those in the lowest, appeared to have lower incidence of PSC cataract. Current dietary guidelines do not include recommended daily legume intake amount but suggest that legumes contribute to overall vegetable consumption as part of a healthy diet and the Grains & Legumes Nutrition Council recommends weekly consumption of 2–3 times<sup>(28)</sup> with one serve of legumes equal to 75 g (1/2 cup) of cooked, dried or canned beans, chickpeas or lentils. The minimum intake for legumes in the highest quintile in our study population is 24.6 g/d (172.2 g/week) equivalent to roughly 2.3 serves/week, meeting the recommended intake level. While we cannot exclude the possibility of chance finding for this association, our observation is in keeping with findings from a previous study in India showing high prevalence of senile cataract and cataract surgery associated with low intake of beans and lentils<sup>(44)</sup>.

In the same BMES population, we have previously shown a protective association between high intakes of protein and incident PSC cataract<sup>(45)</sup>. The India–US case–control study also found increasing intake of protein associated with decreased prevalence of PSC<sup>(46)</sup>. Legumes are a good source of protein and amino acids. In particular, legumes are rich in lysine, an essential amino acid<sup>(47)</sup>. A previous study showed that high levels of lysine and other amino acids in the blood were associated with decreased odds of PSC in a case–control study<sup>(48)</sup>. Although animal studies documented beneficial effect of lysine on cataract formation<sup>(49,50)</sup>, and findings from previous clinic-based studies showed promising effect of Bendazac lysine on cataract<sup>(51,52)</sup>, such findings appeared not to have been translated into preventive or therapeutic management of cataract.

Legumes are also a good source of essential micronutrients, such as thiamin, niacin, folate, riboflavin, Zn, vitamins E and A, and fibre<sup>(47,53)</sup>. Previous epidemiological studies investigating

micronutrient associations with cataract reported mixed findings<sup>(4–7,54)</sup>. Riboflavin has been shown to have a protective association with nuclear<sup>(4,6)</sup> and cortical<sup>(5,54)</sup> but not PSC cataract. We could not find evidence of associations between essential micronutrients and PSC cataract from the literature. A previous BMES report documented no associations between dietary fibre intake and any incident cataract type<sup>(45)</sup>, while the Beaver Dam Eye Study reported decreased prevalence of nuclear cataract among men with high intakes of fibre<sup>(6)</sup>. In the present study, further adjustment with dietary fibre did not alter the association between PSC and legume intake (data not shown).

A limitation for our study is that we used only four food items to estimate wholegrain consumption. We could have underestimated wholegrain consumption in the study population as we did not include wholegrain content of discretionary snack foods such as popcorn or savoury biscuits, although these snack foods are not consumed daily. The Australian wholegrain database<sup>(55,56)</sup> is comprehensive in terms of the foods that have been included. However, during the late 1990s when the BMES 2 participants were examined, wholegrain food options were limited, with much less options available as it is now. We compared the BMES FFQ dataset against the Australian wholegrain database<sup>(55,56)</sup> and found that most wholegrain percentages were similar between the two datasets. However, there were inconsistencies between BMES FFQ dataset and the Australian wholegrain database in regard to the serving sizes of some breakfast cereals. As the serving sizes used in BMES were from the NUTTAB95<sup>(22)</sup>, no further amendments were made to the BMES wholegrain estimates. Nevertheless, we feel that we have covered the major sources of whole grains available in the 1990s and estimated the consumption level as accurately as possible for the BMES population. We cannot exclude potential confounding from unknown or unmeasured confounders such as UV or sunlight exposure.

Strengths of our study include its longitudinal study design, the standardised methods used during each examination, masked grading of cataract using lens photographs with high reproducibility<sup>(20)</sup> and good follow-up of participants (87.4% of survivors were re-examined).

In summary, we found no significant associations of total wholegrain intake or consumption of wholegrain-rich food items at baseline with the 5-year incidence of any of the three cataract types in this older Australian population. We found high consumption level of legumes associated with decreased incidence of PSC, and replication of this association in other studies is needed.

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A. G. T., J. J. W. and V. M. F. formulated the research question; R. G. C. and P. M. designed the BMES cohort study; A. G. T., J. J.



W., J. R. and V. M. F. conducted this particular research; A. G. T. and A. K. analysed data or performed statistical analyses; A. G. T., V. M. F. and J. J. W. wrote and edited the manuscript; A. G. T. and J. J. W. had primary responsibility for final content. All authors revised the text critically for important intellectual content, contributed to and approved the final manuscript.

The authors declare that there are no conflicts of interest.

### Supplementary material

For supplementary material referred to in this article, please visit <https://doi.org/10.1017/S000711452000104X>

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