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Abstract

The purpose was to determine intake of phytoestrogens in a sample of older Australian women, and to investi-gate associated lifestyle factors. Subjects were an age-stratified sample of 511 women aged 40-80 y, randomly selected from the electoral roll and participating in the Longitudinal Assessment of Ageing in Women at the Royal Brisbane and Women's Hospital. A cross-sectional study was conducted to assess isoflavone and lignan intake over the past month from food and supplements using a 112-item phytoestrogen frequency questionnaire. Data were also collected on nutrient intakes, physical activity, smoking, alcohol, non-prescription supplements, hormone therapy, education and occupation. Logistic regression was used to evaluate associations between demographic and lifestyle variables and soy/linseed consumption while controlling for age. Isoflavone intakes were significantly higher in the younger compared to older age groups ($p<0.001$); there were no age-related dif-ferences in lignan intake. Forty-five percent of women consumed at least one serve of a soy and/or linseed item and were defined as a soy/linseed consumer. Median (range) intakes by consumers for isoflavones and lignans (3.9 (0-172) mg/d and 2.4 (0.1-33) mg/d) were higher than intakes by non-consumers (0.004 (0-2.6) mg/d and 1.57 (0.44-4.7) mg/d), respectively ($p<0.001$). Consumers had higher intakes of dietary fibre ($p=0.003$), energy ($p=0.04$) and polyunsaturated fat ($p=0.004$), and higher levels of physical activity ($p=0.006$), socio-economic po-sition ($p<0.001$), education ($p<0.001$) and supplement use ($p<0.001$). Women who consumed soy or linseed foods differed in lifestyle and demographic characteristics suggesting these factors should be considered when investigating associations with chronic disease outcomes.

Keywords

australian, women, lignan, phytoestrogens, associated, demographic, lifestyle, factors, intake, older, isoflavone

Disciplines

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Short Communication

Intake of isoflavone and lignan phytoestrogens and associated demographic and lifestyle factors in older Australian women

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The purpose was to determine intake of phytoestrogens in a sample of older Australian women, and to investigate associated lifestyle factors. Subjects were an age-stratified sample of 511 women aged 40-80 y, randomly selected from the electoral roll and participating in the Longitudinal Assessment of Ageing in Women at the Royal Brisbane and Women's Hospital. A cross-sectional study was conducted to assess isoflavone and lignan intake over the past month from food and supplements using a 112-item phytoestrogen frequency questionnaire. Data were also collected on nutrient intakes, physical activity, smoking, alcohol, non-prescription supplements, hormone therapy, education and occupation. Logistic regression was used to evaluate associations between demographic and lifestyle variables and soy/linseed consumption while controlling for age. Isoflavone intakes were significantly higher in the younger compared to older age groups ($p<0.001$); there were no age-related differences in lignan intake. Forty-five percent of women consumed at least one serve of a soy and/or linseed item and were defined as a soy/linseed consumer. Median (range) intakes by consumers for isoflavones and lignans (3.9 (0-172) mg/d and 2.4 (0.1-33) mg/d) were higher than intakes by non-consumers (0.004 (0-2.6) mg/d and 1.57 (0.44-4.7) mg/d), respectively ($p<0.001$). Consumers had higher intakes of dietary fibre ($p=0.003$), energy ($p=0.04$) and polyunsaturated fat ($p=0.004$), and higher levels of physical activity ($p=0.006$), socio-economic position ($p<0.001$), education ($p<0.001$) and supplement use ($p<0.001$). Women who consumed soy or linseed foods differed in lifestyle and demographic characteristics suggesting these factors should be considered when investigating associations with chronic disease outcomes.

Key Words: phytoestrogens, isoflavones, lignans, life style, socio-demographic

INTRODUCTION

Epidemiological studies have shown that women in Western compared to South-East Asian countries have a higher incidence of chronic diseases, including coronary heart disease and osteoporosis.[1,2] In Asian women the menopausal transition is also associated with lower prevalence specifically of hot flushes.[3] A proposed explanation for these differences is the relatively high consumption of isoflavones, a class of phytoestrogens that are particularly rich in diets based on soy foods.[4] Isoflavones are structurally similar to oestradiol;[5] after ingestion in the diet, they can be absorbed into the body and bind to oestrogen receptors to exert weakly oestrogenic and anti-oestrogenic effects that are tissue-specific and dose-dependent.[6] However demographic and lifestyle factors associated with the intake of isoflavone-rich diets could also contribute to these improved health outcomes.

The pattern of phytoestrogen intake and associated lifestyle factors in Western populations is likely to differ from those in Asian communities and could affect the possible impact of these diets on risk of chronic diseases. Expansion in marketing and consumer interest in the possible health benefits of soy[7] suggest that intake of isoflavones, from both diet and supplements, could be increasing in these societies. Further, few studies have examined phytoestrogen intake in an Australian population or addressed intake of a second class of phytoestrogen, the lignans. Yet their occurrence in a wide range of commonly-consumed plant foods[8], indicates they could be an important contributing source of phytoestrogens in Western communities; the richest known source of lignans is linseed, which is being promoted to the Australian community through incorporation into bread and cereal products.

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Our aims were to estimate intake of isoflavone and lignan phytoestrogens in a group of older Australian women, identify any age related trends and investigate associated demographic and lifestyle variables.

MATERIALS AND METHODS

Subjects

Subjects were a cross-section of 511 women participating in the Nutrition and Endocrine arm of the Longitudinal Assessment of Ageing in Women (LAW), an age-stratified, prospective multidisciplinary study conducted at Royal Brisbane and Women's Hospital, Brisbane. Subjects were randomly selected from the electoral roll within four age cohorts: 40–49, 50–59, 60–69 and 70–79 years. Details have been published previously.[9] At the first visit to the study venue, women completed a phytoestrogen frequency questionnaire, which included questions on use of non-prescription supplements and other lifestyle behaviours. Anthropometric and demographic data were also collected. At the second visit, approximately three months later, data on energy and nutrient intake were collected through a diet history interview.

Assessment of phytoestrogen intake

The phytoestrogen-frequency questionnaire was explained by the dietitian, and then completed by subjects at home and returned by post to the study venue. The 112-item questionnaire contained 30 soy foods, including traditional items such as soybeans, tofu, tempeh and miso, and products developed for the Western market such as soy meat-alternatives, burgers and hotdogs, and tofu yoghurt; and 82 sources of lignans, including linseed bread and crispbreads and commonly-consumed items within the nuts, seeds, legume, cereal, vegetable and fruit groups.

Content of genistein, daidzein and glycitein, the major isoflavones in soy foods, was sourced from international published values,[10] modified to include published Australian data for soybeans, milk, flour grits and flakes, tofu and tempeh.[11, 12] Local food manufacturers were also contacted for information on the phytoestrogen content of specific products such as soy breads. Lignan values were based on published values for enterolactone and enterodiol, measured by an indirect *in vitro* fermentation assay.[8] The questionnaire included eight frequency categories: never; 1/month, 2-3/month, 1/week, 2-4/week, 5-6/week, 1/day and 2-3/day, and subjects were asked to state how much they consumed over the previous month in relation to a specified serve. Intake of phytoestrogens from supplements was assessed by asking subjects to specify use of non-prescription supplements for menopause over the previous month including details of brand name, number of tablets and dose in mg; constituent phytoestrogens were confirmed as required, from details listed on the label. Values for the isoflavone and lignan content per serving were multiplied by the frequency of consumption for each item to calculate the total daily intake. Total phytoestrogen intake was calculated as the sum of isoflavone and lignan intakes.

Demographic and lifestyle characteristics

The diet history involved detailed recall of the types and quantities of food and drinks consumed over the previous month in a 75-minute structured interview with one of two dietitians. A standardised protocol was developed to maximise inter-interviewer reliability. Food models were used to assist estimation of portion sizes and a food frequency list was used to check for possible omissions. Data were analysed into daily energy and nutrient intakes using Foodworks® (Version 3, Xyris Software, Brisbane, Australia) and the AusNut database of Australian foods.

Height and weight were measured with subjects wearing lightweight clothing and no shoes. Height was measured to the nearest 0.1 cm with a stadiometer (Holtain Ltd, Crymych, UK) and weight was measured to the nearest 0.01 kg with a standing scale (Seca Medical Scales, Columbia, MD). Body mass index (BMI) was calculated as: weight (kg) divided by height (m) squared. Waist and hip circumferences were measured to the nearest 0.1 cm and used to calculate waist-hip ratio: waist circumference (cm) divided by hip circumference (cm).

Use in the previous month (yes/no) of non-prescription supplements not specifically associated with menopause was obtained from the phytoestrogen questionnaire; these included vitamins, minerals and herbal preparations, such as Echinacea and St John's Wort. Alcohol intake (g/day) was obtained from the diet history and categorised into: none (0 g/d), up to two standard drinks (≤20 g/day) and over two standard drinks (>20 g/day). Data on never, past or current smoking and use of hormone therapy (HT) were obtained by the clinician. Subjects were classified into one of six levels using self-reported physical activity: 1) moving only for necessary chores; 2) walking or other outdoor activities 1–2 times/wk; 3) walking or other outdoor activities >2/wk; 4) exercising 1–2/wk to the point of perspiring and heavy breathing; 5) exercising >3/wk to the point of perspiring and heavy breathing; 6) keep-fit heavy exercise or sports several times/wk[13]; levels 1 and 2, and levels 4, 5 and 6 were combined for the analyses due to small numbers in individual groups.

Socio-economic position (SEP) was determined by selecting the occupational status of the subject or her spouse, whichever received the higher rating according to the Australian Standard Classification of Occupations.[14] Occupation was classified into one of nine levels: 1) managers and administrators; 2) professionals; 3) associate professionals; 4) tradespersons and related workers; 5) advanced clerical and service workers; 6) intermediate clerical, sales and service workers; 7) intermediate production and transport workers; 8) elementary clerical, sales and service workers; 9) labourers and related workers; levels 5 and 6 and levels 7, 8 and 9 were combined for the analyses. Education level was classified into one of six categories: 1) graduate; 2) current undergraduate or postgraduate student; 3) certificate or diploma; 4) year 12 school; 5) year 10 school; 6) no formal qualification; levels 1 and 2 and levels 4 and 5 were combined for the analyses.

Statistical Analysis

Subjects were classified as soy/linseed consumers if they reported intake of one or more serves of a soy and/or linseed food or product in the previous month. Continuous normal variables were presented as mean (95% confidence interval). Non-normal continuous variables were

presented as median (range); for comparison with previous studies, intake of phytoestrogens was also presented as mean (SD). Categorical variables were presented as frequency (percentage). Kruskal-Wallis tests were used to compare median phytoestrogen intakes (mg/d) between soy/linseed consumers and non-consumers and between age groups. Independent sample t-tests were used to compare mean anthropometric and dietary factors between soy/linseed consumers and non-consumers. Log transformations were used to normalize distributions for BMI, waist:hip ratio, and energy and nutrient intakes. Chi-square tests were used to investigate the differences between groups for categorical demographic and lifestyle variables and logistic regression was used to evaluate the significance of the associations between these variables and soy/linseed group while controlling for age. A value of $p<0.05$ (two-tailed) was considered statistically significant. Study procedures were approved by the Human Ethics committees of Queensland University of Technology and Royal Brisbane and Women's Hospital.

RESULTS

Completed questionnaires were returned by 93% (n=475) of participants and these subjects were included in the statistical analysis. Ninety-eight percent (n=497) of participants reported Caucasian ethnic backgrounds with the remaining participants reporting Asian, Eurasian or Indigenous ethnicity. Forty percent (n=190) reported consumption of at least one soy food and 34% (n=161) consumed at least one serve of linseed; 45% (n=213) consumed at least one serve of a soy and/or linseed item in the previous month and were defined as a soy/linseed consumer. Of the consumers, the proportion was significantly higher in the 40-49 y (28%) and 50-59 y (28%) compared to 60–69 y (24%) and 70–79 y (20%) age groups ($p=0.02$). The prevalence of consumption for specific items was: soy and linseed bread (30%), soy beverages (14%), soy and linseed crispbread (10%), tofu (10%), soy beans (9%), soy grits or cereal (5%), miso (4%), soy crisps (3%), soy sprouts (3%), tofu ice cream/yoghurt (2%), soy cheese (2%), textured vegetable protein (2%) and soy pasta (2%); the remaining 4% included soy bacon, soy hot dogs, soy flour and soy nuts.

Thirteen percent of women reported using at least one non-prescription supplement for menopause in the previous month. Of the users, the proportion was significantly higher in the 50-59 y (40.7%) compared to 40-49 (28.7%), 60-69 (20.3%) and 70-79 year groups (10.2%) ($p=0.01$). The prevalence of consumption for specific supplements was: evening primrose oil (56% of non-prescription supplements used); isoflavones from soy (15.5%), red clover (3.1%) or an unspecified source (7.7%); and Chinese herbs (6.2%); the remaining 11.5% included wild yam, Vitex agnus castus, starflower oil and supplements with a combination of ingredients. No subjects reported taking lignan supplements.

Median phytoestrogen intakes were significantly higher in consumers compared to non-consumers for both isoflavones ($p<0.001$) and lignans ($p<0.001$) (Table 1). Isoflavone intake from the diet and supplements combined ranged from 0 to 173 mg/d, with up to 166 mg/d from supplemental sources and up to 98.0 mg/d from the diet. Isoflavone intake was significantly higher in the 40-49 y and 50-59 y compared to 60-69 y and 70-79 y age groups ($p<0.001$). There was no significant difference in lignan intake between age groups (Table 2).

Overall the mean (95% confidence interval) BMI was 26.3 kg/m^2 (26-27) and WHR was 0.806 (0.79-0.81) (data not shown). Energy intake for the total group was 6.94 (6.8-7.1) MJ/d. The percentage of energy derived from macronutrients was 30.9 (30-32) for fat, 19.3 (19-20) for protein, 45.1 (44-46) for carbohydrate and 2.83 (2.4-3.2) for alcohol. The percentage of energy from types of fat was 11.1 (11-12) for saturated, 11.8 (11-12) for monounsaturated and 5.04 (4.9-5.2) for polyunsaturated. Fibre intake was 24.1 (23 to 25) g/d. There were no significant differences between consumers and non consumers for energy or any nutrients except consumers had a higher intake of dietary fibre (25.4 (24-27) vs 23.2 (22-24) g/d; $p=0.001$) and percent of energy derived from polyunsaturated fat (5.26 (4.9-5.5) vs 4.88 (4.7-5.1); $p=0.02$). In the women aged 40-49 y, waist:hip ratio (95% CI) was 2.5% lower in the consumers compared to non-consumers: 0.78 (0.76-0.80) vs 0.80 (0.79-0.82), respectively ($p=0.04$). There were no further differences in nutrient intakes between age groups. A greater proportion of consumers, compared to non-consumers, reported: higher physical activity ($p=0.04$); SEP ($p=0.01$), higher occupation level ($p<0.01$) and education qualifications ($p<0.001$) and higher use of non-prescription supplements ($p<0.001$); all associations that were significant at the bivariate level remained significant after adjustment for age (Table 3).

DISCUSSION

Phytoestrogen intake

This study examined phytoestrogen intake in relation to demographic and lifestyle factors in an age-stratified group of older Australian women participating in the multidisciplinary LAW study. While not representative of the general population, which has proportionately fewer women in the older age groups,[15] macronutrient intakes observed in LAW women were comparable to those reported for adult Australian women in the National Nutrition Survey[16] of 46.9% of energy derived from carbohydrate, 17.2% from protein, 32.5% from fat and 2.6% from alcohol. Median isoflavone intake from dietary and supplemental sources was 0.033 mg/d. This is comparable to other studies of adult women living in the UK, US, Canada, Ireland, Italy and the Netherlands where median isoflavone intakes have ranged from 0.004 to 0.43 mg/d and mean intakes ranged from 0.0005 to 2.97 mg/d in studies which assessed intake from foods and 1.8 to 2.05 mg/d in studies which included foods and supplements.[17-26]

Our average isoflavone intake was low in comparison to intakes reported in studies of Asian women consuming soy-based diets, where mean isoflavone intakes have ranged from 11 to 54 mg/d.[4,27-33] As there is no formal recommended dietary intake for isoflavones, these values have been used as a guide to optimal intake by virtue of the association between higher isoflavone intakes and the observed lower rates of diseases such as hormone sensitive-cancers, osteoporosis and coronary heart disease in these Asian communities.[2,4,18] However some participants in our study achieved 3 to 15 fold higher intakes of up to

Table 1. Comparison of phytoestrogen intake[†] between soy and/or linseed consumers and non-consumers

	Soy/linseed consumers[‡] (n=214)		Soy/linseed non consumers (n=261)		Total group (n=475)		*p*-value[§]
	Mean (SD) mg/d	Median (range) mg/d	Mean (SD) mg/d	Median (range) mg/d	Mean (SD) mg/d[†]	Median (range) mg/d[†]	
Isoflavones (diet)	8.80 (13.4)	3.48 (0.0-98)	0.028 (0.17)	0.00 (0-2.6)	4.05 (10.07)	0.030 (0.0-98)	<0.001
Isoflavones (supplements)	3.75 (18.0)	0.00 (0.0-166)	0.00 (0.0-0.0)	0.00 (0.0-0.0)	1.67 (12.1)	0.00 (0.0-166)	<0.001
Total isoflavones[‖]	12.54 (22.2)	3.87 (0.0-173)	0.028 (0.17)	0.005 (0.0-2.6)	5.73 (16.1)	0.033 (0.0-173)	<0.001
Lignans (diet)[¶]	3.85 (3.9)	2.40 (0.16-33)	1.67 (0.63)	1.57 (0.44-4.7)	2.71 (3.04)	1.83 (0.16-33)	<0.001
Total phytoestrogens[††]	16.38 (22.8)	7.49 (0.48 – 174)	1.70 (0.65)	1.60 (0.44 – 4.7)	8.44 (17.03)	2.20 (0.44-174)	<0.001

[†]Intake measured by phytoestrogen frequency questionnaire for average daily intake over previous month
[‡]Participants who reported consumption of ≥ one soy/linseed food in the previous month
[§]Kruskal-Wallis test for difference between soy/linseed consumers and non-consumers
[‖]Total isoflavones = isoflavones (diet) + isoflavones (supplements)
[¶]No lignan intake was reported from supplements
[††]Total phytoestrogens = total isoflavones + lignans (diet)

Table 2. Comparison of phytoestrogen intake[†] between age groups

	40 – 49 y (n=112)		50 – 59 y (n=116)		60 – 69 y (n=124)		70 – 79 y (n=123)		*p*-value[‡]
	Mean (SD) mg/d	Median (Range) mg/d	Mean (SD) mg/d	Median (Range) mg/d	Mean (SD) mg/d	Median (Range) mg/d[†]	Mean (SD) mg/d[†]	Median (Range) mg/d[†]	
Isoflavones (diet)	3.99 (11.3)	0.15 (0.0-98)	4.33 (8.9)	0.115 (0.0-47)	4.11 (10.4)	0.035 (0.0-67)	3.80 (9.6)	0.00 (0.0-56)	<0.001
Isoflavones (supplements)	3.66 (18.8)	0.00 (0.0-166)	2.09 (13.1)	0.00 (0.0-120)	1.15 (9.2)	0.00 (0.0-83)	0.00 (0.0-0.0)	0.00 (0.0-0.0)	0.05
Total isoflavones[§]	7.61 (22.1)	0.146 (0.0-173)	6.42 (15.3)	0.179 (0.0-121)	5.27 (15.5)	0.034 (0.0-125)	3.83 (9.67)	0.005 (0.0-56)	<0.001
Lignans (diet)[‖]	2.52 (2.39)	1.71 (0.53-18)	3.18 (4.3)	1.96 (0.66-33)	2.66 (3.1)	1.84 (0.16-26)	2.48 (2.0)	1.82 (0.44-13)	0.42
Total phytoestrogens[¶]	10.13 (22.4)	2.29 (0.53-174)	9.60 (16.5)	2.60 (0.66-121)	7.93 (16.9)	2.09 (0.48-130)	6.31 (10.8)	1.93 (0.44-63)	0.06

[†]Intake measured by phytoestrogen frequency questionnaire for average daily intake over previous month
[‡]Kruskal-Wallis test
[§]Total isoflavones = isoflavones (diet) + isoflavones (supplements)
[‖] No lignan intake was reported from supplements
[¶]Total phytoestrogens = total isoflavones + lignans (diet)

Table 3. Comparison of demographic and lifestyle variables in soy and/linseed consumers and non-consumers

Variable	% Soy/linseed consumers† n=214	% Soy/linseed non-consumers n=261	*p*-value‡	Odds ratio (95% CI)
Physical activity level				
Move only for necessary chores/walking/ other activities 1-2/wk	28	35.9		
Walking/other activities >3/wk	42	46.9		1.17 (0.76-1.8)
Exercising to perspire 1-2 times/wk, heavy exercise or sport several times/wk	30	17.2	0.04	1.87 (1.1-3.2)
Occupation level				
Managers & administrators	15.9	11.5		
Professionals	39.6	24.9		1.14 (0.63-2.1)
Associate professionals	17.4	21.1		0.67 (0.35-1.3)
Tradespersons & related	13.0	18.4		0.57 (0.28-1.1)
Intermediate/advanced clerical, sales, service	10.1	12.3		0.60 (0.29-1.3)
Intermediate production, transport, elementary clerical, sales, labourer	3.9	11.9	0.01	0.33 (0.14-0.79)
Education level				
Under/postgraduate/graduate	18.8	7.4		
Certificate/diploma	22.7	16.3		0.55 (0.27-1.1)
Year 12	12.6	5.1		1.01 (0.43-2.4)
Year 10	26.6	40.9		0.28 (0.15-0.54)
No formal qualifications	19.3	30.4	<0.001	0.31 (0.15-0.62)
Alcohol intake				
None	28	37.2		
Up to 20g/d	58.4	50.6		1.14 (0.41-3.2)
Over 20g/d	10.3	8.0		1.54 (0.57-4.2)
No answer	3.3	4.2	0.39	1.60 (0.52-4.9)
Smoking status				
Never	52.3	57.1		
Current	6.1	9.6		0.23 (0.023-2.3)
Past-smoker	40.2	33		0.11 (0.01-1.3)
No Answer	1.4	0.4	0.09	0.28 (0.027-2.8)
Number of non-prescription supplements used				
None	34.9	49.4		
1-2	32.1	37.3		1.26 (0.82-1.9)
≥3	33	13.3	<0.001	3.46 (2.09-5.7)
HT use				
Never	55.8	55.5		
Past	20.7	20.2		1.22 (0.75-2.0)
Current	23.6	24.3	0.83	1.05 (0.67-1.65)

†Participants who reported intake of at lease one serve of a soy or linseed food in the previous month
‡Logistic regression, adjusted for age

166 mg/d through use of purified isoflavone supplements. High intakes were also reported in a previous observational study of Australian midlife women from Melbourne, in which mean isoflavone intake was 17 mg/d, with 14% of the women above 40 mg/d and 3% more than 100 mg/d.[34] The long-term physiological effects of sustained high intakes from diet or supplements are currently untested.

The average contribution of lignans to total phytoestrogen intake was higher than that of isoflavones (Table 1). In a comprehensive analysis of four major plant lignans, lariciresinol, pinoresinol, secoisolariciresinol and matairesinol, using a customised database of Dutch foods, Milder *et al.* reported a median intake of 0.98 mg/d with the majority (75%) obtained from lariciresinol and pinoresinol.[35] Studies of adult women living in Canada and Sweden that also estimated four lignans, reported median intakes of 0.86 and 1.63 mg/d.[18,36] Earlier studies in the UK and US have reported somewhat lower median intakes from 0.11 to 0.14 mg/d but quantified only two lignans, matairesinol and secoisolariciresinol.[17,26] In our study we estimated lignan intake using an in vitro fermentation method that measures mammalian lignans, enterolactone and enterodiol, which are produced by intestinal bacteria from these plant precursors and therefore would include all sources of plant lignans.[8] Our lignan intake was comparable to intakes from the studies that measured four lignans precursors.

Sources of phytoestrogens

Consumption of at least one soy or linseed product was reported by 45% of participants. Soy and linseed items were emphasised in this study because they are the richest known sources of the two major classes of dietary phytoestrogens, isoflavones and lignans, respectively.[8,37] Non-prescription supplements for menopause were a further source of phytoestrogens.

In our study of women aged 40 to 80 years, the reported prevalence of soy consumption was 40% for intake of at least one soy product in the previous month, with

higher consumption in the younger compared to older women. In groups of American women aged 18 to 37 y,[38] 25 to 59 y and 17-80 y prevalence rates were 34% and 37% for consumption over the previous year and 31% for consumption over the previous three months, respectively.[23,39] In an American study including low-income adults with a mean age of 46.4 y, rates were lower, with 13% consuming a soy product over the previous month, however this study included both men and women[40]. In groups of older women the prevalence has been higher, with 47% of American women aged 50 to 79 y consuming a soy product over the previous 3 mo,[25] and 62% of Melbourne women aged 51 to 62 y consuming a soy food at least once a month in the previous year.[34] However in a UK study of women aged 61.7±9 y, 3.3% of women recorded intake of one or more soy foods in a 7-day food diary.[22] Taken together, these data and the findings of our study suggest that soy consumption in Western countries could vary according to age, socio-economic status and geographical location. However studies are not strictly comparable due to differences in recruitment methods, time intervals, age groups, socio-economic factors and menopause symptom status of participants. The prevalence of consumption of soy foods in these Western countries is consistently lower than that in Asian countries, for example 97% of women in Shanghai reported consumption of soy within one week.[41]

The most frequently reported soy food in our study was soy and linseed bread, which was consumed by 30% of all women in the prior month. The single other Australian study also identified soy or soy and linseed bread as the major source with 38% of all women reporting consumption in the previous year.[34] In contrast, studies of women in Europe and the US identified soy beverages,[40,42] soy beans/sprouts,[25,42] tofu or vegetable dishes as the main sources,[22,23] with no studies citing soy or linseed bread. Soy and linseed bread was developed in Australia over 10 years ago as a functional food containing phytoestrogens, dietary fibre and omega 3 fatty acids. It is marketed especially for menopausal women to reduce hot flushes and promote well being, which could explain the relatively high intake in our group of older women.

Demographic and lifestyle profile of soy/linseed consumers

For comparison with demographic and lifestyle factors, women were classified as either soy/ linseed consumers, defined as intake of one or more serves of a soy and/or linseed food or product in the previous month, or non-consumers.[23] Median total phytoestrogen intake was 4.7 fold higher in consumers than non-consumers, with the major contribution in consumers from dietary isoflavones and a smaller proportion from lignans (Table 1). In addition to soy, isoflavones are also detected in a range of legumes, although quantities are approximately1000-fold lower than in soy beans and in the non-consumers in our study,[37] isoflavone intake from legumes other than soy was low (0.005 mg/d). Besides linseed, lignans are also detected more widely in a range of plant foods including nuts, seeds, legumes, vegetables and fruits, although quantities are 50-fold lower than in linseed.[8] In contrast to isoflavones, lignan intake in non-consumers from plant sources other than linseed was notable, with a median intake of 1.57 mg/d and a range of up to 4.7 mg/d in some individuals.

Significant differences emerged in demographic and lifestyle characteristics between the soy/linseed consumers and non-consumers. Consumers reported a 10% higher intake of dietary fibre (p=0.003) as determined by diet history, and a 13% higher intake of polyunsaturated fat (p=0.004), although there was no significant difference between groups in saturated or monounsaturated fat intake. Total energy intake was 4% higher in consumers (p=0.043), although this difference of approximately 300 kJ/d may not be clinically significant as there were no significant differences in mean body weight or BMI between consumers and non-consumers. There were no differences in alcohol intake, smoking status or HT use.

Research has established that regular physical activity reduces the risk of premature death and disability from a variety of health conditions including cardiovascular disease[43] and osteoporosis.[44] Our results indicated that women who were more physically active and exercised aerobically at least once per week, were also more likely to consume phytoestrogen-rich foods (p=0.04), which could contribute to a reduction in risk of these diseases. Potential health benefits associated with intake of phytoestrogens have included decreased LDL and increased HDL cholesterol,[45] lower blood pressure and increased bone mineral density,[46,47] although not all studies are supportive.[33,48]

Evidence indicates that people of low SEP are less likely to choose actions to prevent disease and this is considered to be a factor that contributes to the disparity in health between low and high SEP groups.[49] Our finding that a greater proportion of consumers were women with longer formal education and a higher SEP is consistent with this evidence as it is possible that women select phytoestrogen rich foods due to a greater understanding or interest in their purported health benefits. The higher general use of non-prescription supplements also suggests that women who consume soy and linseed foods have a greater tendency, compared to non-consumers, to select products that are promoted for their preventive and therapeutic benefits. Other possible explanations are issues such as differing cost and availability of phytoestrogen-rich foods. Findings could be due to associations between SEP or education and the choice of vegetarian/vegan diets, which frequently include soy as a meat substitute. No Australian data were identified in women of a similar age however a study of younger women found that vegetarian and semi-vegetarian women were more likely to have a university degree (59 vs. 44%) although they were also more likely to report a lower income.[50]

The present study extends the findings of previous Australian studies that have shown a beneficial lifestyle profile associated with soy/isoflavone consumption. Worsley *et al.* (2002) in an Adelaide population of 1477 male and female adults reported that subjects who consumed soy bread were more likely to describe their diet as low fat or vegetarian; they also reported a higher use of herbal medicines, minerals or multivitamins.[51] Guthrie *et al.* (2000) reported that Melbourne women aged 51-62 y with isoflavone intakes above 40 mg/d participated in more regular physical activity and had a higher intake of

dietary fibre.[34] Our study included a broader age group of older women, ranging from 40 to 80 years. This group represents the age and gender demographics for which possible benefits of phytoestrogens have most often been attributed, due to the decline in oestrogen concentration after menopause. Age differences were apparent in our study, with a greater proportion of soy consumers in the younger cohorts between 40 to 59 y and therefore likely to be perimenopausal (Table 2). Corresponding intake of isoflavones was also highest in the younger compared to older age groups. Although reasons for consuming soy foods were not explored in our study, a possible explanation for higher intake among women aged 40-59 y is the use of soy foods to prevent or alleviate acute or chronic symptoms of menopause. In contrast to isoflavones, the pattern of lignan intake was more stable and did not differ significantly between age cohorts; further, in each age group, median lignan intake exceeded that of isoflavones, indicating the importance of considering this class of phytoestrogens when investigating health status in older groups of Western women.

A strength of our study was the detailed 112-item phytoestrogen frequency questionnaire that was especially designed to include the major sources of isoflavones and lignans in the Australian market from both diet and supplements. Published Australian analyses for isoflavone content were used for soy beans, soy beverage, soy grits/cereal, tofu and tempeh.[11,12] However there were no available data for the lignan content of Australian foods and our database did not include the content for items such as tea and coffee, which were major contributors in the Dutch diet.[8,35] Further, to our knowledge there are no published data on the lignan content of dietary and herbal supplements; as these are plant-based, they are likely to contain lignans although these were not recognised as ingredients and listed on the supplement label. Therefore our study is likely to have underestimated lignan intake in the LAW study women. Non-prescription supplements were used by 13% of subjects and in some cases provided a dose of isoflavones that met or exceeded intakes provided by a soy-based diet indicating the necessity of including supplements for accurate estimation of intake. Previous studies that did not measure supplements could have underestimated total phytoestrogen intake in their population.[17,19,21-23,34]

CONCLUSIONS

This research provides new data on age-related intake in older Australian women of two classes of phytoestrogens, isoflavones and lignans. To our knowledge, no previous Australian studies have reported on lignan intake. Age-related trends emerged for isoflavones with higher intakes in the younger compared to older age groups, due to greater consumption of soy-based products. Further research is required to determine whether soy foods in the younger women were chosen primarily because of their benefits for treatment or prevention of acute and chronic symptoms of menopause or for factors such as taste and enjoyment. In contrast, average lignan intakes were consistent across the age groups, reflecting the wide distribution of lignans in commonly consumed plant-based foods. Lignan intake exceeded that of isoflavones in each group, indicating the importance of measuring this class of phytoestrogen when assessing potential health benefits in our society.

To further explore our data, we identified soy and linseed consumers, who reported intake of at least one soy and/ or linseed food in the previous month. As expected, isoflavone and lignan intakes were significantly higher in consumers compared to non consumers. Women who consumed soy and/ or linseed products also differed from those who did not with respect to a range of lifestyle and demographic characteristics. This highlights the importance in epidemiological studies of taking into account potentially confounding variables of dietary fibre and fat intake, physical activity, occupation, education and use of non-prescription supplements to obtain a valid assessment of the association between intake of phytoestrogen-rich foods and risk of chronic diseases.

AUTHOR DISCLOSURES

There is no conflict of interest

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Short Communication

Intake of isoflavone and lignan phytoestrogens and associated demographic and lifestyle factors in older Australian women

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澳洲年長女性異黃酮及木質酚攝取與相關的人口學及生活型態因子

本篇目的為探討澳洲年長女性，植物雌激素攝取量與相關的生活型態因子。研究對象為年齡分層之樣本，根據選民登記資料隨機選取而參與皇家布里斯班婦女醫院的女性老化長期評估計劃，年齡為 40-80 歲之女性，共 511 位。執行一橫斷性研究，使用 112 項含植物雌激素食物之頻率問卷，評估參與者在過去一個月，從食物及補充劑中，獲得之異黃酮及木質酚含量。此外也收集營養素攝取量、體能活動、抽菸、飲酒、非處方之補充劑使用、賀爾蒙治療、教育程度及職業等變項。使用羅吉斯回歸，在控制年齡變項後，評估人口學及生活型態因子與植物雌激素攝取之間的相關性。結果發現，較年輕族群之異黃酮攝取量顯著較年老族群高(p<0.001)，而木質酚攝取量在不同年齡族群無差異。有 45% 的參與婦女在過去一個月攝食至少一份含有植物雌激素之食物，被歸類為消費者。消費者每天攝取之異黃酮與木質酚之中位數，分別為 3.9 mg 及 2.4 mg，顯著高於非消費者的攝取量，0.004 mg 及 1.57 mg (p<0.001)。並且消費者有較高之膳食纖維攝取量(p=0.003)、能量攝取(p=0.04)及多元不飽和脂肪酸攝取量(p=0.004)，及較高之體能活動(p=0.006)、社經地位(p<0.001)、教育程度(p<0.001)及補充劑使用(p<0.001)。綜合以上，發現婦女有無攝取含植物雌激素的食物，其生活型態與人口學特性有顯著差異，因此建議在調查慢性疾病相關研究中，應將這些因子納入考慮。

關鍵字：植物雌激素、異黃酮、木質酚、生活型態、社會人口學因子