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ORIGINAL CONTRIBUTION

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Soy intake is related to a lower body mass index in adult women

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Abstract *Background* Experimental and epidemiologic studies suggest that soy may promote weight loss. *Aim of the study* The goal of this study was to examine the relation of soy intake with body weight over the lifespan of women with Caucasian, Japanese, and Native Hawaiian ancestry. *Methods* We assessed the relation between lifetime soy consumption and body mass index (BMI) among 1,418 women in Hawaii. All subjects reported anthropometric measures, regular diet, and soy intake throughout life. The lifetime soy questionnaire was completed again by a subset of 356 women 5 years after study entry and the κ values indicated moderate agreement. We regressed soy intake on BMI at study entry and at age 21 while controlling for confounding variables, computed least square means, and performed trend tests. *Results* Higher soy consumption in adulthood was related to a lower BMI ($P = 0.02$). This association was only significant for Caucasian women and for postmenopausal subjects. The women in the highest category also experienced a smaller annual weight change since age 21 (by 0.05 kg/year) than the low soy intake group ($P = 0.02$). We observed no association between early life soy intake and BMI. High vegetable consumption was significantly associated with a higher soy intake among Caucasian women. *Conclusions* In this study, women consuming more soy during adulthood had a lower BMI, but the relation was primarily observed for Caucasian and postmenopausal subjects. This indicates that the association may be due to other nutritional factors and behaviors common in women with high soy intake.

Key words soy – body mass index – obesity – ethnicity – early life nutrition

Introduction

Obesity is a growing concern due to its increasing prevalence and its related health problems [24]. Because pharmacotherapy has limited effectiveness [17], nutritional strategies for weight management are of great interest. Due to its high protein and low cholesterol content, soy is often used as a meal replacement or dietary component in weight loss regimens [1, 2, 9]. In addition to lowering blood lipids [36], soy or its components may assist in weight control [2, 6], but it is not clear whether the source of dietary protein plays a role in the regula-

EJN 707

tion of food intake and body weight [3]. Potential mechanisms of action for soy include reduction of appetite and increase in satiety [3], weak estrogenic effects [12], and glycemic control [5]. In addition to several animal studies [4, 25], cross-sectional investigations support an association of soy with lower body weight. For example, genistein intake was negatively associated with body mass index (BMI), waist circumference, and total body fat mass among postmenopausal women [11, 12] and soy intake among Japanese subjects was inversely related to BMI [34]. Intervention studies are less consistent. Whereas a high soy diet was more effective in lowering body weight than a lifestyle education program in a German trial [7] and a soy-based low-calorie diet led to a greater decrease in body fat among Chinese subjects than a traditional low-calorie diet [18], comparisons of dairy-based and soy-based preparations [2, 13, 23], isoflavone-enriched and regular cereal bars [31], and soy diets with control diets [5, 28, 33] did not detect any significant differences. Most previous research explored the effects of soy on body weight over a few months and without attention to ethnicity [6]. One reason to hypothesize a weight lowering effect of soy foods is the high consumption in Asian countries [22] where obesity is less common than in Western countries [34]. Hawaii's multicultural population allows the comparison of ethnic groups with different traditional diets. The purpose of this study was to examine the relation of soy intake with body weight over the lifespan of women with Caucasian, Japanese, and Native Hawaiian ancestry.

Subjects and methods

Study design and population

Participants comprised 1,492 women from two previous studies: the Breast Estrogen and Nutrition study (BEAN) [21] and a nested case–control (NCC) study of mammographic densities [20]. We excluded 74 women because they did not return the life-time soy questionnaire (LTSQ), leaving 1,418 participants: 225 healthy premenopausal BEAN study subjects and 1,193 women from the NCC, of which 562 had breast cancer. NCC subjects were primarily postmenopausal women selected from the Multiethnic Cohort (MEC). The BEAN study excluded women on hormone medications and those with a self-reported soy intake of more than six servings/week [21]. Both studies were approved by the Committee on Human Studies at the University of Hawaii and the Institutional Review Boards of the participating clinics. All women signed an informed consent form.

Data collection

All women completed the same 26-page self-administered Diet and Health Questionnaire (DHQ) and a LTSQ at study entry. Approximately 5 years later (range 3–6 years), 356 of the NCC women who participated in a new project filled out the LTSQ a second time. The DHQ included a detailed dietary history, as well as information about demographics, body weight and height, and medication history [15]. Based on self-reports, ethnicity was classified into four categories: Native Hawaiian, Japanese, Caucasian, and Others which included African-Americans, Chinese, Filipina, Koreans, Latina, and other Pacific Islanders. BMI (kg/m^2) was calculated from self-reported height and weight at the time of study entry and at age 21. The BMI distributions were approximately normal after excluding values outside of 15–50 (kg/m^2). We estimated annual weight change (kg/year) by dividing the difference in weight at study entry and at age 21 by the number of years.

To estimate soy exposure since birth, we designed a one-page questionnaire modeled after a validated soy questionnaire [32]. It included sections for the following stages of life: infancy (first year), childhood (1–9 years), adolescence (10–19 years), early adulthood (20–29 years), and late adulthood (30+ years). Participants marked the annual frequency of usual serving sizes for four categories of soy foods (tofu; soy beans and sprouts; soy milk and drinks; and other soy products). To obtain a summary score for early life (0–19 years) and adulthood (since age 20), we added the frequencies of intake by stage and computed the mean annual intake as number of servings. Then we created binary variables, low versus high soy intake, using the median intake. The cut off point for soy intake during early life was any versus no soy intake, and during adulthood it was 36 servings/year [21]. Finally, we classified adult intake into four categories: none, <1 servings/week, >1 servings/week, and >2 servings/week. We also created a four-level variable that combined intake during early life and adulthood.

Statistical analysis

All statistical analyses were performed with the SAS© software package (SAS Institute INC., Cary, NC, USA, 1999). Characteristics of the study population were stratified by ethnicity and results were given as means and standard deviations for continuous variables and as frequencies and percents for categorical variables. Analysis of variance for continuous variables and chi-square tests for categorical variables were used to test for group differences. Pair-wise comparisons between ethnic groups were performed for variables of interest

Table 1 Characteristics of the study population by ethnicity

Characteristic	Native Hawaiian	Japanese	Caucasian	Other	*P**
Number	254	606	456	102	–
Age at study entry	53.9 ± 8.9	57.9 ± 9.4	55.0 ± 10.4	49.9 ± 9.3	<0.0001
College education	67 (26.4%)	258 (42.6%)	240 (52.6%)	51 (50.0%)	<0.0001
Breast cancer diagnosis	71 (27.9%)	274 (45.2%)	181 (39.7%)	36 (35.3%)	<0.0001
Born in the USA	252 (99.2%)	568 (93.7%)	413 (90.57%)	65 (63.7%)	<0.0001
Never smoker	133 (52.4%)	423 (69.9%)	239 (52.5%)	72 (70.6%)	<0.0001
Number of children	3.0 ± 1.8	2.2 ± 1.4	2.1 ± 1.6	2.1 ± 1.4	<0.0001
Age at menarche >13 years	107 (42.1%)	260 (42.9%)	221 (48.5%)	62 (60.8%)	0.003
Age at first live birth >30 years	16 (6.3%)	71 (11.7%)	57 (12.5%)	16 (15.7%)	0.03
Postmenopausal	159 (62.6%)	446 (73.6%)	289 (63.4%)	43 (42.2%)	<0.0001
BMI at study entry (kg/m^2)	28.3 ± 5.9	24.1 ± 3.86	25.5 ± 5.39	25.1 ± 4.9	<0.0001
BMI at 21 years old (kg/m^2)	22.0 ± 3.33	20.6 ± 2.35	21.0 ± 2.61	20.4 ± 2.69	<0.0001
Weight change (kg/year)	0.55 ± 0.45	0.25 ± 0.26	0.39 ± 0.43	0.43 ± 0.44	<0.0001
Physical activity (METs)	1.58 ± 0.31	1.57 ± 0.25	1.62 ± 0.25	1.576 ± 0.28	0.04
Alcohol intake >1 drink/day	21 (8.3%)	20 (3.3%)	114 (25.0%)	6 (5.9%)	<0.0001
Total energy intake (kcal/day)	2135 ± 1077	1839 ± 645	1836 ± 647	1989 ± 8609	<0.0001
Meat intake (g/day)	93.5 ± 75.6	73.9 ± 55.3	80.0 ± 67.2	111.5 ± 92.7	<0.0001
Vegetable intake (g/day)	393 ± 312	309 ± 184	307 ± 190	266 ± 186	<0.0001
Early life soy intake (servings/week)	1.5 ± 3.3	2.7 ± 3.9	0.2 ± 0.9	1.4 ± 2.7	<0.0001
Adult soy intake (servings/week)	2.9 ± 4.9	3.4 ± 5.0	1.1 ± 2.2	2.5 ± 5.3	<0.0001
Lifetime soy intake (servings/week)	2.3 ± 4.1	3.2 ± 4.4	0.75 ± 1.5	2.1 ± 4.2	<0.0001
Combined soy intake					
Low early life/low adulthood	53 (20.7%)	29 (4.8%)	299 (65.6%)	34 (33.3%)	<0.0001
High early life/low adulthood	61 (24.0%)	142 (23.4%)	26 (5.7%)	21 (20.6%)	<0.0001
Low early life/high adulthood	22 (8.7%)	28 (4.6%)	97 (21.3%)	6 (5.9%)	<0.0001
High early life/high adulthood	118 (46.5%)	407 (67.2%)	34 (7.5%)	41 (40.2%)	<0.0001

* *P* for difference was obtained by chi-square test for categorical variables and by ANOVA for continuous variables

using Tukey's Studentized Range test that controls for the Type 1 experiment wise error rate.

To assess reliability of questionnaire recall, we used PROC FREQ in SAS to calculate the weighted κ values by stage of life for the 356 women who completed the LTSQ twice [16].

We applied analysis of variance to examine the association of soy intake with BMI and to estimate least square means by soy intake category. To test for trend, we included a linear variable with values of 0, 1, 2, and 3 (none, <1 serving/week, >1 serving/week, and >2 servings/week, respectively) into the model. We performed this analysis separately for early life soy intake and adulthood soy intake, for BMI at study entry and at age 21, by ethnic group, and by menopausal status. To explore the combined variable for early life soy intake, adult soy intake, and body weight change since age 21, contrast analyses were used. All models were adjusted for confounding variables where appropriate: ethnicity; age (continuous); education (high school or lower; college or vocational; and graduate school); percent calories from fat (continuous); energy intake (continuous); physical activity as metabolic equivalents (METs) estimated from self-reported hours of sleeping, sitting, light activity, moderate activity, and vigorous activity; alcohol intake (none or any); age at menarche (<13, 13–14, and 14+); number of children (0–1, 2–3, and 3+); and age at first live birth (not applicable, <age 21, 21–30, and 30+). All *P* values were two-tailed and an α-level of 0.05 was considered statistically significant.

Results

We observed significant differences among ethnic groups for all population characteristics of interest (Table 1). BMI at study entry and BMI at age 21 were significantly higher for Native Hawaiians, with intermediate levels for Caucasians, and lowest levels for Japanese and Others. Caucasian subjects had the highest percentage of no soy intake in early life and in adulthood, but soy intake was higher during adulthood than early in life for all ethnic groups. Specifically, 30% of Native Hawaiians, 9% of Japanese, 87% of Caucasians, and 40% of Others reported no soy intake during childhood, while 11% of Native Hawaiians, 3% of Japanese, 40% of Caucasians, and 15% of Others consumed no soy during adulthood. Japanese soy intake early in life was significantly greater by 1.2, 1.3, and 2.5 servings/week than for Native Hawaiians, Others, and Caucasians, respectively. For soy intake during adulthood, the Japanese intake was only significantly greater than the Caucasian intake (2.3 servings/week). At the same time, Caucasians had a significantly lower soy intake in

Table 2 The relation of soy intake and body mass index (BMI) in 1,418 women by ethnicity

Soy intake	*N*	All	Native Hawaiian	Japanese	Caucasian	Others
BMI (kg/m^2) at study entry[a]						
Early life						
None	568	25.5	28.1	23.5	25.5	25.4
<1 serving/week	401	26.0	28.1	24.4	27.2	24.9
≥1 serving/week	449	25.8	28.8	24.1	23.0	24.8
P for trend		0.66	0.49	0.63	0.88	0.55
Adulthood						
None	244	26.0	28.1	25.2	25.8	23.2
<1 serving/week	421	26.1	28.8	24.2	26.2	26.0
1-2 serving/week	313	25.5	27.0	24.1	25.5	25.4
≥2 servings/week	440	25.3	28.8	24.0	23.7	24.2
P for trend		**0.02**	0.89	0.36	**0.01**	0.96
Combined						
Low early and low adult	415	25.9	28.8	23.5	25.8	25.5
High early and low adult	250	26.2	28.4	24.5	28.0	24.8
Low early and high adult	153	24.6	26.4	23.5	24.5	25.2
High early and high adult	600	25.7	28.4	24.1	24.6	24.8
P for low versus high adult		**0.002**	0.19	0.72	**0.001**	0.93
BMI (kg/m^2) at age 21[b]						
Early life						
None	568	20.9	21.9	20.7	21.0	19.8
<1 serving/week	401	21.1	21.9	20.6	21.4	21.1
≥1 serving/week	449	21.1	22.2	20.6	20.6	20.6
P for trend		0.55	0.60	0.84	0.99	0.19
Weight (kg/year) change since age 21[a]						
Combined soy intake						
Low early and low adult	415	0.41	0.59	0.21	0.40	0.53
High early and low adult	250	0.41	0.54	0.28	0.56	0.40
Low early and high adult	153	0.34	0.54	0.19	0.34	0.68
High early and high adult	600	0.38	0.55	0.25	0.33	0.35
P for low versus high adult		**0.02**	0.74	0.44	**0.01**	0.64

[a]Adjusted for ethnicity, age, education, fat intake, energy intake, physical activity, drinking status, age of menarche, number of children, and age at first live birth
[b]Adjusted for ethnicity and age of menarche

early life and adulthood than Native Hawaiians and Others. Caucasian women had the highest physical activity level, energy intake, and alcohol consumption, whereas Japanese women had the lowest. Meat intake was lowest in Japanese, intermediate in Caucasians, and highest in Native Hawaiians.

For the 356 women with repeated information on soy intake, the κ values indicated substantial agreement during childhood and adolescence (0.61 and 0.62). For early adulthood and late adulthood, the overall comparison showed moderate agreement (0.55–0.46). After stratification by ethnicity, the agreement was fair with κ values ranging from 0.31 to 0.58.

We observed a significant trend for the association of adult soy intake with BMI at study entry ($P = 0.02$) (Table 2). Women reporting more than two soy servings/week had a 0.7 kg/m^2 lower BMI than women consuming no soy foods. This relation was stronger for the 937 postmenopausal women (1.2 kg/m^2; $P = 0.01$), while no trend was seen for the 481 premenopausal women ($P = 0.76$). When analyzed separately by ethnicity, the trend was only significant for Caucasians ($P = 0.01$) with a 2.1 kg/m^2 lower BMI in the highest than in the lowest intake group. The trend in Japanese women was in the same direction although not significant ($P = 0.36$). Early life soy intake was not related to BMI at study entry or at age 21.

The overall model with combined adult and child soy intake was significant ($P < 0.0001$). The contrast between low versus high adult soy intake was significant ($P = 0.002$) with a difference of 0.9 kg/m^2 between the low and high adult soy intake categories. This difference was of similar magnitude in pre- and postmenopausal women ($P = 0.08$ and 0.01). After stratification by ethnicity, the effect was only significant for Caucasians ($P = 0.001$) with a 2.35 kg/m^2 lower BMI for the high adult soy intake category as compared to the low intake category. When weight change since age 21 was examined in relation to the combined soy intake variable, the contrast between low and high adulthood soy intake was significant ($P = 0.02$); women in the low soy intake groups had a yearly weight gain of 0.05 kg/year greater than those in the high soy intake groups. Again, the contrast was only significant for Caucasian women ($P = 0.01$). Although this effect was significant, it is important to note that women in the high adult soy intake category were on average only two kilos lighter than the other women. When we excluded the 225 BEAN subjects from the analysis, the results in Table 2 did not change substantially (data not shown).

In a model that examined the association of energy intake, vegetable, fruit, meat, fat, and carbohydrate intake, and physical activity level with adult soy intake while adjusting for covariates, only vegetable intake remained statistically significant ($P < 0.0001$). A higher vegetable consumption was significantly associated with higher soy intake. This association was observed in all ethnic groups after stratification (data not shown).

Discussion

This study of lifetime soy intake and BMI provides some support for the hypothesis that women who consume soy as part of their regular diet have a lower body weight. Eating more soy foods in adulthood predicted a lower BMI and a lower annual weight gain since age 21 for Caucasians and, to a lesser degree, for Japanese. The weaker association among pre- than postmenopausal women may have been the result of the smaller number of premenopausal women. Early life soy intake was not associated with BMI at age 21 or during adulthood. Although 90% of Caucasians did not report any soy foods during childhood, close to 50% reported soy consumption as adults. Because soy intake was positively associated with vegetable intake, the lower BMI in the high soy intake category may be a result of healthier lifestyles and nutritional behaviors rather than a direct effect of soy foods.

If soy had an effect on BMI, the association is expected to be similar among all ethnic groups unless intake varied so little within a group as to mask an effect. Therefore, it is odd that we observed a relation with BMI among Caucasian women who are the lowest soy consumers. It appears likely that the Caucasian women who chose to incorporate soy into their diets as adults despite growing up without soy foods may have done so as a result of health concerns, whereas women with other ethnic backgrounds continued to consume soy for other reasons. Our findings in combination with other reports suggest that soy may be an indicator of a healthy lifestyle [11, 12, 34]. Although a study in primarily Caucasian women observed an inverse association between total body fat and dietary isoflavone intake, the subjects with the greatest genistein intake also reported the highest physical activity levels [12]. Moreover, fish intake in a cross-sectional investigation in Japan was associated with a lower BMI to a similar degree as soy consumption [34]. The cross-sectional study in women that described significant associations with soy intake may have also been confounded by lifestyle factors [11, 12]. Despite some positive weight loss findings during interventions [7, 18, 23], the evidence from randomized trials indicates little effect of soy on body weight [2, 5, 13, 23, 28, 31, 33]. In particular, a well-controlled trial of a soy shake compared to a casein shake showed not difference in weight loss by assigned group [2]. The discrepancies across studies may be due to different types of soy or supplements consumed by the study subjects [8]. The beneficial effects of isoflavones, such as increasing HDL cholesterol [36], may be modified once removed from the food source; phytoestrogen-rich foods may be preferable over extracted soy isoflavones [35]. Men and women may also experience distinct effects from soy [36] and the short duration of some studies may have prevented the detection of effects that may only become apparent after long-term soy consumption [6]. Finally, differences in gut microflora and equol production may have confounded the findings of this and other reports [26].

This study had several limitations. The LTSQ required women to recall their soy intake at different stages during their lives. The long time period aggravates the well described problems with food frequency questionnaires [14], but a study in adults who recalled their adolescent diet after a 4-year period found acceptable agreement [19]. Our own questionnaire provided reasonable reproducibility after 5 years with κ values ranging from fair to moderate although these values were somewhat lower than in another study that reported intraclass correlation coefficients of 0.30–0.62 for food items [29]. Epidemiologic studies that have presented significant associations between adolescent diet and breast cancer risk also support the idea that adolescent diet can be assessed with some level of validity [27]. A different problem is that BMI does not represent body fat very well in general and across ethnic groups [30]. Therefore, waist circumference may have been a better measure of adiposity, but this information was not available. Combining two previous studies should not have affected the findings much since all women completed the same questionnaires. The fact that only women with less than six soy servings/week were part of the BEAN study may have introduced some bias, but they constituted only 16% of the study population and excluding them did not alter our findings.

Despite the limitations of this study, the results offer some new insights into the relation of soy intake with body weight. Since, we do not know yet which component of soy may affect body weight [6], the lack of standardization in reporting soy and isoflavone intake makes it challenging to compare the different studies [8]. Our nutritional database used aglycone equivalent of isoflavone levels measured in locally consumed soy foods [10]. The study design of many previous studies did also not allow a separation of possible soy effects from those due to calorie restriction. Our results indicate that women consuming more soy foods during adulthood, in particular Caucasian and postmenopausal subjects, may have a lower BMI, but this may be due to other nutritional factors and behaviors common in women with high soy intake, e.g., lower meat or higher physical activity, although we only observed a significant association of soy intake with vegetable consumption. Randomized feeding studies with well-characterized components are needed to disentangle this question. Given the widespread advertising and the unsubstantiated claims for weight loss products containing soy, it is important to improve our understanding whether soy foods may assist in weight loss or maintenance.

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