Prevalence of seafood allergy in the United States determined by a random telephone survey

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Background: Seafood allergy is potentially severe, but the prevalence of this group of food allergies in the US population has not been determined.
Objective: To estimate the prevalence of seafood (fish, shellfish) allergy in the United States.
Methods: We performed a nationwide, cross-sectional, random telephone survey by using a standardized questionnaire. Criteria were established in advance to define seafood allergy by report of convincing symptoms and physician evaluation.
Results: A total of 5529 households completed the survey (67.3% participation rate), representing a census of 14,948 individuals. Fish or shellfish allergy defined by established criteria was reported in 5.9% (95% CI, 5.3%-6.6%) of households and among individuals as follows: 2.3% (95% CI, 2%-2.5%) for any seafood allergy, 2% for shellfish, 0.4% for fish, and 0.2% for both types. Seafood allergy was more common in adults compared with children (2.8% vs 0.6%; $P < .001$) and in women compared with men (3.6% vs 2%; $P < .001$). Recurrent reactions were reported by 58%, dyspnea or throat tightness was reported by more than 50%, and 16% were treated with epinephrine. Despite this level of acuity, only 8.6% were prescribed self-injectable epinephrine. The rate of reactions to multiple fish among those with any fish allergy was 67%; for Crustacea the rate was 38%, and for mollusks the rate was 49%; only 14% with crustacean allergy reported a mollusk allergy.
Conclusions: Physician-diagnosed and/or convincing seafood allergy is reported by 2.3% of the general population, or approximately 6.6 million Americans. Affected individuals typically report recurrent and sometimes severe reactions, indicating that seafood allergy represents a significant health concern. (J Allergy Clin Immunol 2004;114:-159-65.)

Key words: *Prevalence, fish, Crustacea, shellfish, hypersensitivity, food allergy, anaphylaxis, telephone survey*

Seafood is common in the US diet, with a per capita consumption rate of 15.6 lb in 2002, up from 12.5 lb in 1970.[1] Seafood includes vertebrate finned fish such as cod, salmon, and tuna, *Crustacea* such as shrimp, crab, and lobster, and mollusks such as squid, scallop, clams, and snails. Adverse reactions to seafood include immunologic ones such as IgE antibody-mediated allergy triggered by ingestion[2,3] or inhalation of proteins,[4] and adverse reactions that are not immune-based caused by toxins or infectious contaminants.[5] Allergic reactions to ingestion of seafood may include life-threatening anaphylaxis[2,6-8] and occupational exposure to skin contact and vapors may cause asthma and contact dermatitis.[4] The major allergenic proteins have been identified in fish parvalbumin[9] and in shellfish tropomyosin.[10] Allergic cross-reactivity among fish and among shellfish is high but variable.[2,8,11]

Despite the ubiquity of seafood in the diet and the potential severity of allergic reactions, no studies have specifically addressed the prevalence of seafood allergy in the general population. However, the rate of seafood allergy in allergy referral populations and among persons with food-induced anaphylaxis has been reported, particularly for children. In a series of 355 children with food allergy in Spain, 30% had fish and 6.8% shellfish allergy.[12] In Italy, among 54 episodes of food-induced anaphylaxis in children, 30% were caused by fish,[13] and in Philadelphia, Pa, 4 of 14 (29%) were caused by seafood.[14] Among 90 children and adults with anaphylaxis to foods in England, 4.4% were caused by seafood,[15] and among 89 persons evaluated in a University-based allergy practice in Tennessee, 29% reacted to *Crustacea* and 1% to tuna.[16] In a registry of food-induced fatal anaphylaxis, 1 of 32 deaths was caused by fish,[7] and in a report of 7 deaths, 1 was attributed to crab and 1 to fish.[6]

The scope of seafood allergy in the general population has been partially addressed. In a survey of 17,280 adults age 20 to 44 years from 15 countries that defined allergy or intolerance to a variety of foods on the basis of a subject's report that the food "nearly always" caused "illness or trouble," 2.3% reported shrimp, 2.3% oyster, and 2.2%

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fish allergy or intolerance.[17] The type of foods most commonly provoking allergy or intolerance varied by country, with seafood most commonly incriminated in Norway and Spain. In a birth cohort of 1456 infants, skin prick tests to fish were positive at age 4 years in 0.8%, but clinical correlation was not provided.[18] In 1992, Lehrer et al[19] estimated that 0.1% of the general population would have seafood allergy. However, it is clear that atopic diseases[20,21] and food allergy[22,23] have increased over the years, and no studies have directly addressed the rate of seafood allergy in the United States.

The objective of this study was to determine the rate of self-reported seafood allergy in the United States. We present here the result of a nationwide, cross-sectional, random telephone survey by using a standardized questionnaire in which we defined seafood allergy according to report of convincing symptoms and physician evaluations.

METHODS

Survey methods

The survey was a nationwide, cross-sectional, computer-assisted telephone interview of households performed from October 1, 2002, to December 10, 2002 by IMR, an AdvancePCS Company (Hunt Valley, Md). A random sampling of telephone numbers was generated by the Genesys Sampling System (Fort Washington, Pa). Non-residential calls were excluded from analysis. A specific household was called at different times of the day and on different days to optimize contact with a resident. At least 10 attempts were made to contact a resident of each household. If at the time of a household contact there was no adult age 18 or older available, an effort was made to call back at an appropriate time. To minimize selection bias, subjects were called afternoons, evenings, and on weekends.

Selection of eligible respondents and rules for surrogates

Regulations pertaining to consent procedures and subject confidentiality were strictly observed, and the study was approved by the Essex Institutional Review Board. Respondents were eligible if they were 18 years old or older, were living in the household, and understood the questions without a language, mental, or hearing barrier. The initial age-eligible household respondent was invited to participate in the survey. Respondents not allergic to seafood were asked to identify individuals within the household who were allergic. If the affected individual was a minor, the initial respondent acted as a surrogate. If this respondent was unable to act as a surrogate, another adult was sought. If the affected individuals were adults and unavailable, the household was recontacted until the affected individual could be interviewed. If no household resident was allergic to seafood, census data were collected. In households with 1 or more persons allergic to seafood, the entire interview was conducted with each allergic person (or surrogate, if the allergic person was <18 years old). Adults with a seafood allergy identified by a surrogate were included in the prevalence estimate, but details of reactions in adults were only included when the affected adult was personally interviewed.

Questionnaire contents, definitions, and data analysis

The questionnaire was developed by the authors (S. H. S. and H. A. S.) with assistance from the Medical Advisory Board of the Food Allergy and Anaphylaxis Network and Samuel B. Lehrer, PhD, Tulane University, and with guidance of Carol Leotta, PhD, and Joshua Liberman, PhD, of IMR to create a telephone interview script. The questionnaire was pilot-tested before data collection to ensure that the computerized algorithms were working properly, that respondents interpreted questions correctly, and that data were captured in accordance with the hard copy questionnaire. The questionnaire included detailed questions about finfish and shellfish separately, and no questions included the generic term *seafood*. In this report, the specific terms *fish* (eg, finned fish such as tuna, cod, and salmon) and *shellfish* (eg, crustacean shellfish such as shrimp and lobster and mollusks or bivalves such as clams and squid) are used, as appropriate, or the term *seafood* is used to refer to both groups. The interview began with screening questions used to identify individuals within the household who had seafood allergy; these included a history of allergic reaction to fish or shellfish and/or a positive allergy test (eg, positive allergy skin test or blood test) to these foods. Additional questions were administered depending on responses and included those regarding the most severe fish and/or shellfish reactions, lifetime recurrence of fish and/or shellfish reactions, lifetime seafood-related medical history, household census, allergy medical information, and demographic data. Race or ethnicity was determined only from the responding household member, and calculations assumed that all household members were of the same race or ethnicity.

Diagnostic algorithms were used to categorize respondents into 1 of 9 case groups on the basis of their interview responses. The case groups were no allergy, physician-diagnosed allergy (by self-report of physician confirmation), convincing allergy (levels 1-4), and probable allergy (levels 1-3). For calculation of prevalence rates, individuals were considered allergic if they fell into the physician-diagnosed or 1 of the convincing categories. Determination of diagnostic categories was performed independently for fish and shellfish and is summarized in Table I along with the number of persons surveyed who qualified for each category. The convincing symptoms included hives or urticaria, angioedema, trouble breathing, oral pruritus, and throat closing. Lightheadedness and coughing were considered convincing symptoms only if they were named in combination with a supportive symptom such as nausea, abdominal pain, vomiting, or diarrhea.

Data management was performed by using SAS statistical software for Windows (version 8; SAS Inc, Cary, NC); telephone interview data were converted into SAS data sets for analysis. Differences in proportions between groups were tested by χ^2 analysis (2-sided Fisher exact test). Prevalence is reported here as the number of individuals who met the case definition for seafood allergy divided by the total population at risk.

RESULTS

Participation rate

A total of 10,966 households were contacted: 3585 (32.6%) refused to participate, and an additional 1592 (14.6%) were ineligible (age <18 years with no adult available, 110; language barrier, 743; confusion or hearing problems, 438; willing but ultimately unable to schedule interview, 301). After adjustment of the refusal rate for the estimated proportion of ineligible households among refusals, the participation rate was 67.3%. Of the total of 5789 participating households, 5529 (95.5%) completed the entire interview and represented a total census of 14,948 individuals.

Demographic characteristics of participants and reported rates of seafood allergy

A total of 327 households (5.9%; 95% CI, 5.3%-6.6%) reported 1 or more individuals with seafood allergy; 9

TABLE I. Categorization of allergy according to self-reported features

	Physician-diagnosed	Convincing-1	Convincing-2	Convincing-3	Convincing-4	Probable-1	Probable-2	Probable-3
Reports physician diagnosis	X							
Convincing symptoms		X			X	X	X	
Supportive symptoms				X				X
Lightheaded or coughing				X			X	X
Treatment with epinephrine and or antihistamines			X	X			X	X
More than 1 reaction				X	X			X
Time to reaction		<2 h	<2 h	<2 h	2-12 h	2-12 h	2-12 h	2-12 h
Physician/emergency department treatment			X		X			
Usually cannot ingest the food				X				X
Number with reported finfish allergy*	29	26	1	2	0	6	0	0
Number with reported shellfish allergy†	107	172	14	3	7	12	0	0

*Thirty-nine reported allergy but did not meet criteria, and 15 reported allergy but did not provide enough details for categorization.
†Ninety-two reported allergy but did not meet criteria.

TABLE II. Prevalence of seafood allergy by age

		Type of allergy							
	Total sample population	Fish*		Shellfish†		Both fish and shellfish‡		Any seafood§	
Age (y)	N = 14,948	n	% (±95% CI)	n	% (±95% CI)	n	% (±95% CI)	n	% (±95% CI)
0-5	997	0	0.0 (0.0-0.4)	1	0.1 (0.0-0.6)	0	0.0 (0.0-0.04)	1	0.1 (0.0-0.6)
6-17	2610	6	0.2 (0.1-0.5)	17	0.7 (0.4-1.0)	3	0.1 (0.0-0.3)	20	0.8 (0.5-1.2)
18-40	4336	23	0.5 (0.3-0.8)	95	2.2 (1.8-2.7)	7	0.2 (0.1-0.3)	111	2.6 (2.1-3.1)
41-60	3604	19	0.5 (0.3-0.8)	110	3.1 (2.5-3.7)	10	0.3 (0.1-0.5)	119	3.3 (2.8-3.9)
61+	1876	5	0.3 (0.1-0.6)	49	2.6 (1.9-3.4)	1	0.1 (0.0-0.3)	53	2.8 (2.1-3.7)
Not reported (<18)	207	1	0.5 (0.0-2.7)	2	1.0 (0.0-3.5)	1	0.5 (0.0-2.7)	2	1.0 (0.1-3.5)
Not reported (>18)	1318	4	0.3 (0.0-0.8)	29	2.2 (1.5-3.1)	3	0.2 (0.0-0.7)	30	2.3 (1.5-3.2)
Overall‡§	14948	58	0.4 (0.3-0.5)	303	2.0 (1.8-2.3)	25	0.2 (0.1-0.3)	336	2.3 (2.0-2.5)

*Any physician-diagnosed or convincing fish allergy, irrespective of shellfish allergy.
†Any physician-diagnosed or convincing shellfish allergy, irrespective of fish allergy.
‡Individuals who met criteria for physician-diagnosed or convincing fish and shellfish allergy.
§Individuals who met criteria for either physician-diagnosed or convincing fish or shellfish allergy.

households reported 2 persons with seafood allergy. Rates of reported allergy to fish, shellfish, or both according to age are shown in Table II. The lifetime prevalence rate for reported seafood allergy in the total population was 2.3%, and 0.4%, 2.0%, and 0.2% for fish allergy, shellfish allergy, and both, respectively. The rates for children were significantly lower than for adults, as follows: fish allergy, 0.2% versus 0.5% ($P = .02$); shellfish allergy, 0.5% versus 2.5% ($P < .001$); and any seafood allergy, 0.6% versus 2.8% ($P < .001$).

The distribution of reported seafood allergy according to race or ethnicity and sex according to age is shown in Table III. Female subjects compared with male subjects reported a higher rate of shellfish (2.6% vs 1.5%; $P < .001$) and fish allergy (0.6% vs 0.2%; $P < .001$). The differences in prevalence rate by age and sex indicate a tendency toward a higher rate of seafood allergy in boys compared with girls (0.8% vs 0.5%; P = NS) and women compared with men (3.6% vs 2.0%; $P < .001$). No significant variation in prevalence was reported by geographic location (data not shown). Regarding race or ethnicity, the highest rates of seafood allergy were reported by black subjects ($P = .005$) and subjects who refused or did not report race, with the greatest differences in reported shellfish allergy ($P < .001$). The fraction of physician-diagnosed shellfish allergy was similar between white subjects and black subjects (38% vs 40%, respectively), but in the group without reported race, fewer had physician-diagnosed allergy (11%).

Adjusted prevalence estimates

The distribution of seafood allergy diagnoses by diagnostic categories is shown in Table I. The data presented thus far exclude the persons for whom a report of seafood allergy was not physician-diagnosed or convincing. If all persons with self-reported seafood

TABLE III. Prevalence of seafood allergy by race/ethnicity and sex/age

Comparison group	Total sample population* N = 14,948	Type of allergy							
		Fish†		Shellfish‡		Both fish and shellfish§		Any seafood	
		n	% (±95% CI)	n	% (±95% CI)	n	% (±95% CI)	n	% (±95% CI)
White	11176	28	0.3 (0.2-0.4)	197	1.8 (1.5-2.0)	12	0.1 (0.0-0.2)	213	1.9 (1.6-2.2)
Black	1508	16	1.1 (0.6-1.7)	47	3.1 (2.3-4.1)	7	0.5 (0.2-1.2)	56	3.7 (2.8-4.8)
Other	1909	11	0.6 (0.3-1.0)	41	2.2 (1.6-2.9)	4	0.2 (0.0-0.5)	48	2.5 (1.9-3.3)
Refused/not reported	355	3	0.9 (0.2-2.5)	18	5.0 (3.0-7.8)	2	0.6 (0.0-2.0)	19	5.4 (3.3-8.2)
Male (<18 y)	1936	4	0.2 (0.0-0.4)	13	0.7 (0.3-1.0)	2	0.1 (0.0-0.3)	15	0.8 (0.4-1.2)
Female (<18 y)	1726	3	0.2 (0.0-0.4)	7	0.4 (0.1-0.7)	2	0.1 (0.0-0.3)	8	0.5 (0.1-0.8)
Male (>18 y)	5018	11	0.2 (0.1-0.4)	93	1.9 (1.5-2.2)	5	0.1 (0.0-0.2)	99	2.0 (1.6-2.4)
Female (>18 y)	5726	39	0.7 (0.5-0.9)	183	3.2 (2.7-3.7)	15	0.3 (0.1-0.4)	207	3.6 (3.1-4.1)

*Does not include data concerning sex for the following: 542 participants missing sex and whose allergy type is unknown, 152 participants <18 years whose sex is unknown, and 390 participants >18 years whose sex is unknown.
†Any physician-diagnosed or convincing finfish allergy, irrespective of shellfish allergy.
‡Any physician-diagnosed or convincing shellfish allergy, irrespective of fish allergy.
§Individuals who met criteria for physician-diagnosed or convincing fish and shellfish allergy.
Individuals who met criteria for either physician-diagnosed or convincing fish or shellfish allergy.

TABLE IV. Estimates of seafood allergy prevalence according to various criteria or definitions

Category of evidence	Fish, n (%)	Shellfish, n (%)	Both, n (%)	Any seafood, n (%)
Physician-diagnosed/ convincing	58 (0.4)	303 (2.0)	25 (0.2)	336 (2.3)
Any self-report	118 (0.8)	407 (2.7)	37 (0.3)	488 (3.3)
Recurrent reactions	31 (0.2)	174 (1.2)	11 (0.0)	194 (1.3)
Required epinephrine therapy	18 (0.1)	46 (0.3)	9 (0.0)	55 (0.4)
Physician-diagnosed and allergy test positive	16 (0.1)	63 (0.4)	10 (0.0)	69 (0.5)

allergy were included, the overall rates of self-reported allergy would have been higher (3.3%; 95% CI, 3%-3.6%), as indicated in Table IV. Table IV also shows various prevalence estimates considering more conservative diagnostic criteria, or symptoms or treatment parameters.

Clinical features of seafood allergy

Age of onset of allergy was during adulthood for 39.7% with fish and 60.1% with shellfish allergy. For 8.6% with fish and 10% with shellfish allergy, the worst reactions described were to skin contact and/or inhalation, and some of these persons were able to ingest the foods. As indicated in Table IV, multiple reactions were common, with the following distribution: fish, 2 to 5 reactions in 32.8%, >6 in 20.7%; and shellfish, 2 to 5 reactions in 42.2% and >6 in 15.2%. The distribution of symptoms during an individual's worst reaction are shown in Fig 1. In 55% of the finfish reactions and 40% of shellfish reactions, evaluation by a physician or care in an emergency department was sought. Despite the array of severe symptoms and administration of epinephrine to 16% of persons with allergy, prescription of epinephrine for self-injection was reported by only 8.6% of participants.

Estimation of the rate of allergies to multiple types of seafood is complicated by the fact that not all participants were exposed to all types of seafood and that, after a reaction, avoidance of multiple types of seafood is often undertaken. Among those with fish allergy (n = 58), 19 subjects reported a reaction to only 1 type, 5 subjects to 2 types, and 13 subjects to 3 to 9 types, and the remainder were uncertain. Among those with allergy to shrimp, lobster, and/or crab who indicated specific knowledge of an allergy (n = 232), 62% indicated allergy to 1, 20% to 2, and 18% to all 3 types. Among scallops, clams, oysters, and mussels (n = 67), 51% reacted to 1, 19% to 2, 8% to 3, and 22% to all 4 types. Forty-one persons with shellfish allergy (14%) reported an allergy to both 1 or more crustaceans and 1 or more mollusks or bivalves.

The most common types of seafood to which allergy was reported are shown in Fig 2. Also indicated in Fig 2 are the numbers of persons who reported an allergy to a type of seafood but could at least sometimes eat the food at the time of the survey. For fish, individuals in this category (n = 12) indicated that they believed they had outgrown the allergy (2), had only mild reactions (2), were less reactive depending on cooking (2), were able to eat small amounts (2), took medications to eat it (1), or did not know (3). Among those with shellfish allergy who sometimes ate the food (n = 85), the most common responses included the following: outgrew the allergy (12), varied by cooking or preparation (21), varied by amount eaten (8), reactions were to contact only (5), and did not know (16).

DISCUSSION

Seafood allergy is potentially severe,[6,8] and because it is often noted in adults, it is often considered long-lived.[24,25] The prevalence of seafood allergy has not been well characterized. In this study of the general population, 3.3% reported themselves to have a "seafood allergy."

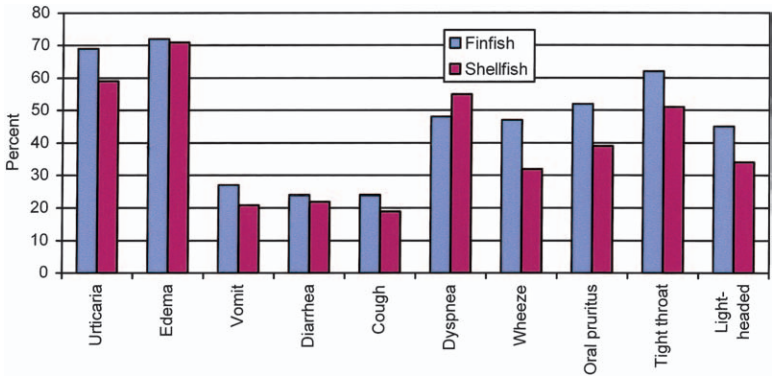

FIG 1. Distribution of symptoms reported as occurring during the most severe reactions.

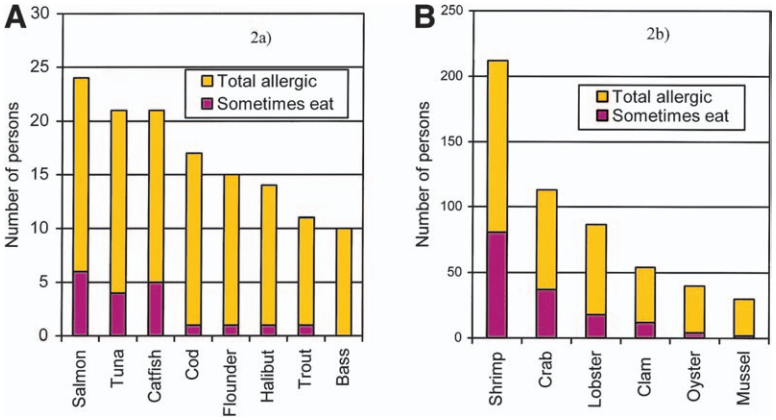

FIG 2. Rate of reported reactions according to type of fish **(A)** or shellfish **(B)**.

After application of more conservative definitions of an allergic response as outlined in Table I, 2.3% of the general population reported a convincing and/or physician-diagnosed seafood allergy, and seafood allergy was reported by at least 1 individual in 5.9% of US households.

This study disclosed several other important heretofore not well-documented features of seafood allergy. Regarding age and sex, seafood allergy tends to be more common among boys and women. This age-sex distribution remains unexplained but was similar in previous surveys of peanut allergy[23,26] and anaphylaxis.[15,27] Black subjects reported the highest rate of seafood allergy. To determine the reason for this observation, eg, cultural eating differences, associations with environmental exposures,[28] or other explanations, further studies are needed. This study showed that seafood allergy often develops in adulthood, that most persons have multiple reactions, and that reactions often include severe symptoms. Epinephrine was used for 16% of the individuals with reported seafood allergy. Despite the apparent acuity of reactions, only 8.6% were prescribed epinephrine to be carried for self-injection. This discrepancy highlights the need for improved awareness and education about seafood allergies.

This study also elucidates several important and understudied clinical features of seafood allergy. Cross-reactions among fish and shellfish have been investigated by oral challenge studies in small groups (<10) of patients. For finfish, 30% of children[2] and >66% of adults[8] reacted to multiple types, and for shellfish 50% to 100% react to >1 type.[29] Conversely, there are also reports of an isolated allergy to 1 type of fish[30] or 1 variety of shrimp.[31] Here, reactions reported to multiple fish among those with any fish allergy accounted for 67%; *Crustacea*, 38%; and mollusks, 49%; only 14% with crustacean allergy reported a mollusk allergy. Although these data are limited by self-selected diets, this study further confirms the impression that cross-reactivity is common but not universal, and that individualization of the allergy diagnostic evaluation toward related seafood must be undertaken with care because reactions are sometimes severe. Another concern is potential permanency. Loss of fish allergy over childhood was shown by Kajosaari,[32] and loss of fish allergy in adulthood was recently reported,[33] but the extent of this phenomenon is not well studied. In the current study, 3.5% of persons allergic to fish and 4% of persons allergic to shellfish reported outgrowing their allergies.

There are several limitations in this study, some in regard to telephone surveys and others concerning the self-reported diagnosis of allergy. Regarding telephone surveys, overrepresentation of persons with a high socioeconomic status may have occurred because homes without telephones were excluded[34] and homes with multiple-voice lines were more likely to be selected. The participants represent a convenience sample rather than a true random sample because households who were impossible to contact were not included. However, efforts were made to reduce this potential bias by using multiple call-back and varying call times. Ethnic and racial biases may also have occurred. In comparing the various demographic features of respondents to the US 2000 census with the demographic data of the participants (data not shown), the mean deviation in age distribution was 0.8%, and the disparity in sex distribution was small (49.9% female subjects in this survey; 50.9% in the US census). Race or ethnic disparities were also small, with equivalent rates of white subjects (74.8% in the survey; 75.1% in the US census) but with underrepresentation of black subjects (10.1% in the survey; 12.3% US Census), Hispanics (6.1% vs 12.5%), and Asians (2.4% vs 3.6%). However, survey respondents often refused or did not report race or ethnicity (2.4%). Finally, the prevalence estimates presented in this report are slightly conservative because the population surveyed was not adjusted for subjects who reported no or unknown seafood exposure (0.9%).

There were also limitations of the survey instruments in identifying true allergy. The gold standard for diagnosing food allergy is the double-blind, placebo-controlled oral food challenge.[35] It was clearly not practical in this study to challenge subjects culled from the general population. Instead, to estimate the prevalence of IgE antibody-mediated allergy, we established criteria of convincing symptoms as described. This approach was used previously for peanut and tree nut allergic reactions[23] with good accuracy (97%),[36] and other questionnaire studies of peanut allergy noted a false-positive rate of 13% (with a surrogate respondent for children, using allergy skin prick tests to peanut to indicate sensitivity) to 14% (in adults).[37,38] However, in contrast with peanut or tree nut allergy, we considered here the possibility of nonallergic adverse reactions to seafood as a confounding issue. The primary masquerader of IgE-mediated reactions is scombroid fish poisoning.[39] Several types of fish (eg, tuna, bluefish, and others) when spoiled may cause reactions that mimic IgE-mediated ones with flushing and urticaria. In 1999, 19 cases of scombroid poisoning were reported in the United States.[5] Presumably, recurrent reactions of scombroid poisoning in 1 person would be unlikely, and documentation of a positive skin test to fish in a person whose only reaction was actually a scombroid poisoning would also be unlikely. Therefore, among reactions to potentially contaminated fish in this study, only 2 adults may have actually had scombroid poisoning, which does not significantly affect the prevalence estimates. Essentially all other types of seafood poisoning (eg, toxins such as Ciguatoxin or contamination such as Botulism and others) would not cause symptoms that would be included in our definitions of confirmed or convincing reactions.[5] Exclusion of symptoms that coincide with contamination-related illness may have underestimated allergic reactions, because non−IgE-mediated reactions would also be excluded. Although it is was not possible here to verify allergy through directed study (oral challenge, tests for IgE, review of medical records, and so forth, that could result in exclusion of some subjects), we have presented a variety of conservative estimates (Table I, Table IV) that indicate a high rate of seafood allergy even with very strict diagnostic criteria.

In summary, 3.3% of the general US population reported a seafood allergy, and the cumulative prevalence, based on self-reported physician-diagnosed and/or convincing reactions, was 2.3% (95% CI, 2%-2.5%). Of these, 58% reported recurrent reactions, and 16% were treated with epinephrine for a reaction. Considering the US population in 2002, an estimated 6.6 million Americans have a seafood allergy, indicating a significant public health concern deserving further investigation for diagnosis and management. Furthermore, previous estimates of food-allergic disease in adults of approximately 2%[25,40] should be revised. Because 77% of adults allergic to seafood in this study did not report other food allergies (data not shown), it may be calculated that 2.2% of the adult population has an isolated seafood allergy, significantly raising the estimated adult population allergic to food to approximately 4%.

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REFERENCES

1. Americans ate more seafood in 2002. National Oceanic and Atmospheric Administration. September 2003. Available at: http://www.publicaffairs.noaa.gov/releases2003/sep03/noaa03105.html. Accessed December 2003.
2. Bernhisel-Broadbent J, Scanlon SM, Sampson HA. Fish hypersensitivity, I: in vitro and oral challenge results in fish-allergic patients. J Allergy Clin Immunol 1992;89:730-7.
3. James JM, Helm RM, Burks AW, Lehrer SB. Comparison of pediatric and adult IgE antibody binding to fish proteins. Ann Allergy Asthma Immunol 1997;79:131-7.
4. Jeebhay MF, Robbins TG, Lehrer SB, Lopata AL. Occupational seafood allergy; a review. Occup Environ Med 2001;58:553-62.
5. Chegini S, Metcalfe DD. Seafood toxins. In: Metcalfe DD, Sampson HA, Simon RA, editors. Food allergy: adverse reactions to foods and food additives. Malden (MA): Blackwell Science; 2003. p. 487-510.
6. Yunginger JW, Sweeney KG, Sturner WQ, Giannandra LA, Teigland JD, Bray M, et al. Fatal food-induced anaphylaxis. JAMA 1988;260:1450-2.
7. Bock SA, Muñoz-Furlong A, Sampson HA. Fatalities due to anaphylactic reactions to foods. J Allergy Clin Immunol 2001;107:191-3.
8. Helbling A, Haydel R, McCants ML, Musmand JJ, El Dahr J, Lehrer SB. Fish allergy: is cross-reactivity among fish species relevant? double-blind placebo-controlled food challenge studies of fish allergic adults. Ann Allergy Asthma Immunol 1999;83:517-23.
9. Swoboda I, Bugajska-Schretter A, Verdino P, Keller W, Sperr WR, Valent P, et al. Recombinant carp parvalbumin, the major cross-reactive fish allergen: a tool for diagnosis and therapy of fish allergy. J Immmunol 2002;168:4576-84.

10. Ayuso R, Lehrer SB, Reese G. Identification of continuous, allergenic regions of the major shrimp allergen Pen a 1 (tropomyosin). Int Arch Allergy Immunol 2002;127:27-37.
11. Lehrer SB, McCants ML. Reactivity of IgE antibodies with crustacea and oyster allergens: evidence for common antigenic structures. J Allergy Clin Immunol 1987;80:133-9.
12. Crespo JF, Pascual C, Burks AW, Helm RM, Esteban MM. Frequency of food allergy in a pediatric population from Spain. Pediatr Allergy Immunol 1995;6:39-43.
13. Novembre E, Cianferoni A, Bernardini R, Mugnaini L, Caffarelli C, Cavagni G, et al. Anaphylaxis in children: clinical and allergologic features. Pediatrics 1998;101:E8.
14. Dibs SD, Baker MD. Anaphylaxis in children: a 5-year experience. Pediatrics 1997;99:E7.
15. Pumphrey RSH, Stanworth SJ. The clinical spectrum of anaphylaxis in north-west England. Clin Exp Allergy 1996;26:1364-70.
16. Kemp SF, Lockey RF, Wolf BL, Lieberman P. Anaphylaxis: a review of 266 cases. Arch Intern Med 1995;155:1749-54.
17. Woods RK, Abramson M, Bailey M, Walters EH. International prevalences of reported food allergies and intolerances. Comparisons arising from the European Community Respiratory Health Survey (ECRHS) 1991-1994. Eur J Clin Nutr 2001;55:298-304.
18. Arshad SH, Tariq SM, Matthews S, Hakim E. Sensitization to common allergens and its association with allergic disorders at age 4 years: a whole population birth cohort study. Pediatrics 2001;108:E33.
19. Lehrer SB, Helbling A, Daul CB. Seafood allergy: prevalence and treatment. J Food Saf 1992;13:61-76.
20. Liu AH, Murphy JR. Hygiene hypothesis: fact or fiction? J Allergy Clin Immunol 2003;111:471-8.
21. Broadfield E, McKeever TM, Scrivener S, Venn A, Lewis SA, Britton J. Increase in the prevalence of allergen skin sensitization in successive birth cohorts. J Allergy Clin Immunol 2002;109:969-74.
22. Grundy J, Matthews S, Bateman B, Dean T, Arshad SH. Rising prevalence of allergy to peanut in children: data from 2 sequential cohorts. J Allergy Clin Immunol 2002;110:784-9.
23. Sicherer SH, Munoz-Furlong A, Sampson HA. Prevalence of peanut and tree nut allergy in the United States determined by means of a random digit dial telephone survey: a five year follow-up study. J Allergy Clin Immunol 2003;112:1203-7.
24. Wood RA. The natural history of food allergy. Pediatrics 2003;111:1631-7.
25. Sampson HA. Food allergy, part 1: immunopathogenesis and clinical disorders. J Allergy Clin Immunol 1999;103:717-28.
26. Emmett SE, Angus FJ, Fry JS, Lee PN. Perceived prevalence of peanut allergy in Great Britain and its association with other atopic conditions and with peanut allergy in other household members. Allergy 1999;54:380-5.
27. Yocum MW, Khan DA. Assessment of patients who have experienced anaphylaxis: a 3-year survey. Mayo Clin Proc 1994;69:16-23.
28. Stevenson LA, Gergen PJ, Hoover DR, Rosenstreich D, Mannino DM, Matte TD. Sociodemographic correlates of indoor allergen sensitivity among United States children. J Allergy Clin Immunol 2001;108:747-52.
29. Waring NP, Daul CB, deShazo RD, McCants ML, Lehrer SB. Hypersensitivity reactions to ingested crustacea: clinical evaluation and diagnostic studies in shrimp-sensitive individuals. J Allergy Clin Immunol 1985;76:440-5.
30. Kelso JM, Jones RT, Yunginger JW. Monospecific allergy to swordfish. Ann Allergy Asthma Immunol 1996;77:227-8.
31. Morgan JE, O'Neil CE, Daul CB, Lehrer SB. Species-specific shrimp allergens: RAST and RAST-inhibition studies. J Allergy Clin Immunol 1989;83:1112-7.
32. Kajosaari M. Food allergy in Finnish children aged 1 to 6 years. Acta Paediatr Scand 1982;71:815-9.
33. Solensky R. Resolution of fish allergy: a case report. Ann Allergy Asthma Immunol 2003;91:411-2.
34. Waksberg J. Sampling methods for random digit dialing. J Am Stat Assoc 1978;73:40-6.
35. Bock SA, Sampson HA, Atkins FM, Zeiger RS, Lehrer S, Sachs M, et al. Double-blind, placebo-controlled food challenge (DBPCFC) as an office procedure: a manual. J Allergy Clin Immunol 1988;82:986-97.
36. Sicherer SH, Burks AW, Sampson HA. Clinical features of acute allergic reactions to peanut and tree nuts in children. Pediatrics 1998;102:E6.
37. Hourihane JO, Dean TP, Warner JO. Peanut allergy in relation to heredity, maternal diet, and other atopic diseases: results of a questionnaire survey, skin prick testing, and food challenges. BMJ 1996;313:518-21.
38. Hourihane JO, Kilburn SA, Dean P, Warner JO. Clinical characteristics of peanut allergy. Clin Exp Allergy 1997;27:634-9.
39. Attaran RR, Probst F. Histamine fish poisoning: a common but frequently misdiagnosed condition. Emerg Med J 2002;19:474-5.
40. Young E, Stoneham MD, Petruckevitch A, Barton J, Rona R. A population study of food intolerance. Lancet 1994;343:1127-30.