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A systematic review of the determinants of seafood consumption

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Abstract

Although seafood is considered to be an important part of a balanced diet, many national food consumption surveys suggest that seafood is not consumed in sufficient amounts. As consumers are moving to diversify their diet from animal-based protein, it is important to understand the factors influencing consumption of marine foods. This review aims to assess the characteristics of seafood consumers as well as the influences on seafood consumption in Europe, USA, Canada, Australia and New Zealand. Systematic search strategies were used to identify relevant journal articles from three electronic databases (PubMed, Web of Science and Embase). Three searches were carried out and identified 4405 unique publications from which 121 met the criteria for the review process. The reviewed studies revealed that seafood consumers were more likely to be older, more affluent and more physically active and were less likely to smoke compared with non-seafood consumers. Sex and BMI did not appear to have a directional association with seafood consumption. The most commonly reported barriers to seafood consumption were cost, followed by sensory or physical barriers, health and nutritional beliefs, habits, availability and cooking skills. The most commonly reported influences were beliefs about the contribution of seafood to health, environmental influences and personal preferences. Based on the findings of this review, future intervention strategies to increase seafood consumption may need to consider affordability and education in terms of health, nutrition and cooking skills. More research is needed to explore the effectiveness of specific interventions at increasing the consumption of seafood.

Key words: **Seafood: Determinants: Reviews: Fish: Influences on consumption**

Fish and seafood are widely consumed throughout the world[1] and are an important source of vitamins A, D and E, as well as essential *n*-3 fatty acids which contribute to healthy eye, brain and neurological development in babies and children[2]. Seafood is also a major source of lean protein worldwide, and according to a report conducted by the FAO of the United Nations, approximately 6 % of dietary protein comes from seafood globally[1]. Seafood is also generally rich in iodine, important in proper thyroid function, and its consumption can contribute towards meeting the daily requirement of 150 µg/d for adults[3]. Whilst there are a number of positive reasons to consume seafood from a nutritional point of view, it is important to consider both sustainability of the type of seafood that is consumed[4,5], as well as biotoxicity risk[6,7]. The European Commission[8] recommends 1–4 servings of fish a week to maximise the health benefits as well as minimise biotoxicity risks associated with seafood consumption. From a sustainability aspect, the 2019 EAT-Lancet report recommends consumption of 28 g/d (up to 100 g) of fish to keep within planetary bounds and prevent depletion of fish stocks[4]. In Ireland and the UK, healthy eating guidelines currently recommend the consumption of two servings of about 140 g of fish/week, one to be oily fish. According to the Irish National Adult Nutrition Survey (2010) data, fish was consumed by half of 18–64-year-olds and two-thirds of those aged 65 years and over in the Republic of Ireland. However, the average daily intake of fish in National Adult Nutrition Survey consumers was approximately 50 g, which is below the recommended amounts[9].

Furthermore, intakes across European countries vary greatly[10] and national consumption surveys often lack information about less commonly consumed foods as data collection focuses on a snapshot of habitual diet[9]. For example, in the last Irish national food consumption survey, from 133 050 rows of data generated, only twelve of these related to shellfish which is not sufficient data to assess contribution to nutrient intake or undertake risk exposure assessment in this food group.

This review aims to examine published literature from Western countries (Europe, Australia, New Zealand, USA and Canada) and investigate, at a time when consumers are moving to diversify their diet from animal-based protein[11], the characteristics of seafood consumers, as well as the barriers and influences on seafood consumption. Seafood is defined as 'animals from the sea that can be eaten, especially fish or sea creatures with shells'; thus, this paper will focus on the consumption of both fish and shellfish.

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Materials and methods

To our knowledge, this is the first review to examine the determinants of seafood consumption across multiple countries. Our primary objective was to characterise seafood consumers residing in Western countries (Europe, Australia, New Zealand, USA and Canada). The primary review question was 'What are the characteristics of seafood consumers in developed countries?'. Secondary considerations included 'What are the associations (positive and negative) on seafood consumption in these countries?'. A comprehensive search following Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines was conducted in Embase, MEDLINE and Web of Science of papers published between 1 October 2008 and 31 December 2018. Two additional searches for papers published between 1 January 2019 and 27 August 2019 were performed on 27 August 2019 and 29 August 2020, in order to identify any papers that were missed in the original search, using identical terms and databases as the initial search. The search strategy included a combination of the following search terms: ((factors OR influences OR determinants OR indicators) AND (fish OR seafood OR shellfish OR marine products) AND (diet OR dietary intake OR intake OR consumption)). When performing the search on the Web of Science database, categories were refined to 'Nutrition and Dietetics', 'Behavioural Sciences', 'Public Environmental Occupational Health' and 'Environment Sciences'. For each concept, the database-specific indexing terms (MeSH or Web of Science terms) were searched in addition to terms in the title or abstract. Studies were only considered if meeting the following criteria – full-text articles on human studies conducted between 1 January 2008 and 31 December 2018 among adults (18+ years) in Europe, USA, Canada, Australia and New Zealand, published in English. The search was limited to adults (>18 years); studies involving children were excluded. Studies which did not statistically analyse associations between seafood consumption and the following factors were excluded: age, sex, education, affluence, BMI, physical activity and smoking. Included studies explored participants' intakes of fish, seafood and/or proxy measures of same, such as marine PUFA or perceived barriers to or drivers of seafood/fish consumption.

In the final selected papers, the following key characteristics were captured: (a) study methodologies: the country and year of the study, the number of subjects and their sex, age (age range), intake of specific foods, food groups and/or nutrients being investigated, dietary assessment method and dietary analysis; (b) the characteristics of seafood consumers described in the study, findings of stratified analysis by sex, age, education, income, smoking, BMI or physical activity and (c) barriers to and drivers of seafood consumption that exist in these populations, which were consequently categorised under the following broader terms: personal preference, availability/convenience, cost, cooking skills, environment, health and nutritional beliefs and psychological traits.

Results

Combined, the three literature searches yielded 1961 titles of potentially relevant articles in PubMed, 1828 titles in Embase and 2460 titles in Web of Science. A total of 4406 unique articles were found, after duplicates were removed. Following this, a further 3899 articles were excluded following consideration of title and abstract. The remaining articles (n 506) were screened based on inclusion/exclusion criteria. Two authors independently assessed abstracts of potentially eligible papers that examined fish and seafood intake and decided on inclusion of full-text articles, resolving any differences by discussion and, when necessary, in consultation with the review team. Of the remaining 121 articles, eighty-two articles explored the characteristics of seafood consumers and thirty-seven articles explored the barriers and/or influences on seafood consumption (Fig. 1). These papers and their findings are described below.

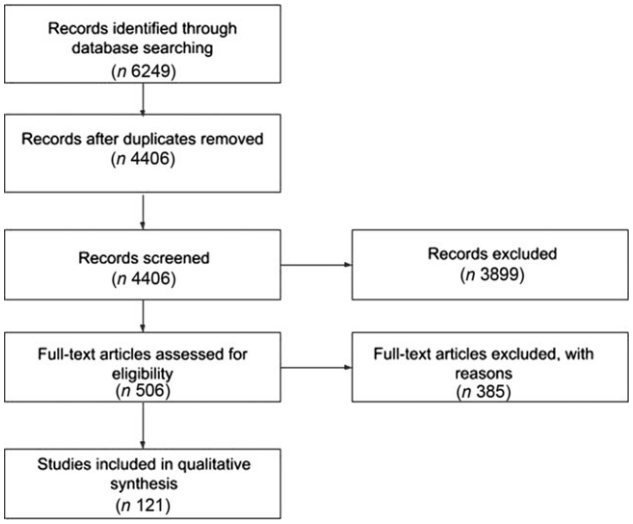


Fig. 1. Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) flow chart of the searching and selection process.

Details of each study included in this review are summarised in Table 1 and online Supplementary Table S1. Online Supplementary Table S1 lists the papers that analysed the characteristics of seafood consumers. Studies were conducted in the USA (n 27), Europe (n 49), Australia (n 2), New Zealand (n 1) and Canada (n 3). Sixty-seven percentage of all papers exploring the characteristics of seafood consumers collected dietary intake data using only a FFQ, 7 % used 24-h recalls, 5 % used a food record, 10 % used interviews and 9 % used a combination of these methods. Fifty-two studies had a cross-sectional design, and thirty were prospective observational studies. This review focuses on the following characteristics: age, sex, affluence, education, BMI, physical activity and smoking.

Characteristics of seafood consumers

Age. Fifty-four papers explored the association between seafood consumption and age. There was a positive association between older age and seafood consumption in forty-three of these papers[12–53]. The largest study to find this was Patel *et al.*[39] which analysed 21 984 participants' seafood intake. A smaller number of studies (n 5) noted a positive association between seafood consumption and younger age group[54–58]; however, these studies all had a sample population of over

50 years of age, their interpretation of young age was relative only to their specific study cohort.

Sex. Thirty-one papers explored the association between seafood consumption and sex. Overall, there was not a strong directional association between sex and seafood consumption observed. Seafood consumption was higher in men than in women in thirteen papers[13,16,18,22,29,31,52–54,59–62] as opposed to eleven papers[13,24,32,34,37,40,51,54–56,63] finding that women were more likely to consume seafood. Two of these studies found that men are more likely to consume fried fish[13,54], and according to three studies, women were more likely to consume non-fried fish[13,54,63]. For a number of papers, no association between fish consumption and sex was identified[14,19,47,58,64–68]. When considering intakes by sex, it is important to consider adjustments for energy intake in the analysis. The following papers adjusted for energy intake[23,27,28,30,36,38,43,52–56,67], with the remaining studies not adjusting for energy intake, or not reporting adjustment.

Affluence. The majority of papers (twenty-one out of twenty-nine) that explored correlations between affluence and seafood intake found that seafood consumption had a positive association with higher socio-economic status, higher income or higher employment level. One paper saw a positive association between seafood consumption and lower socio-economic status status, income or employment level; however, this was associated with fried fish intake specifically[69]. There was no association between these variables according to seven papers[12,24,31,32,44,59,70]. The most common association found was between higher income and seafood consumption[14,18,26,37,63–65,71–75]. Significant associations were also seen between seafood consumption and higher socio-economic status[56,76–79] as well as higher grade employment[13,27,29,41].

Education. Thirty-six papers found a significant association between education and seafood consumption. Most of these studies highlighted a positive association between education level and seafood consumption[14–16,18,23,26–30,36–39,41,42,45,46,51–55,57–59,63,64,71,73,80–84]. An association between higher education and non-fried fish consumption, as well as an association between lower education level and fried fish consumption, was reported in two papers[54,57]. Whilst the majority of papers did find a positive association, Karlsson *et al.*[43] and Hansen-Krone *et al.*[33] both found that a higher percentage of people with lower fish intake had higher education or a university degree compared with those in the highest quintile of fish intake. However, despite statistical significance, in Hansen-Krone *et al.*'s[33] study, the second highest percentage of people in higher education was seen in those who consumed fish 2–2·9 times/week. There was no significant association found between seafood intake and education in thirteen studies[12,19,21,22,24,31,34,44,56,65,68,70,85].

BMI. There was no clear association between BMI and seafood consumption with results varying greatly between studies. While thirty-four papers explored the association between BMI range and seafood intake, there was a correlation between higher fish intake and lower BMI in six of these papers[14,23,40,51,57,63]. Two papers found an association between higher BMI and lower seafood intake[27,31]. An association was seen between higher fish intake and higher BMI in eleven papers[20–22,34,36,43,54,57,68,86,87]. Three of these papers[14,54,86] stated that this association was with fried fish intake specifically. Fifteen papers found no association[15,19,28,33,37,44,52,55,56,58,66,70,85,88,89].

Smoking. Seafood consumption was positively associated with smoking in five papers[34,36,56,57,86]. Belin *et al.*[57] specified that this association was with fried fish intake. Strøm *et al.*[27] found that women who consumed less fish were more likely to be smokers. High fish intake was associated with former or non-smoking in twenty-seven studies[14,15,21,22,34,37–42,51,52,54,55,58,63,67,73,83,84,88–93]. Eleven papers did not find an association between fish intake and smoking[12,19,20,23,28,33,43,64,68,70,87].

Physical activity. Twenty-nine studies included in this review explored associations between seafood consumption and physical activity level. Most studies (*n* 22) found that higher seafood intake was associated with higher engagement in physical activity[16,20,22,27,33,36–39,51,52,56,57,63,64,67,84–86,88–90]. Three of these studies found a significant association between physical activity level and non-fried fish consumption specifically[57,63,64]. Belin *et al.*[57] also found a correlation between fried fish consumption and lower physical activity levels in adults. A correlation between higher non-fried fish intake and low physical activity was observed in one paper[14].

Influences on seafood consumption

Thirty-seven studies examined participant reported influences on seafood consumption (Table 1). Twenty of these reported on barriers to the consumption of seafood and twenty reported on drivers of consumption of seafood, with ten papers reporting on both. Studies were conducted in the USA (*n* 5), Europe (*n* 22), Canada (*n* 3) and Australia (*n* 7). All studies had a cross-sectional design. The selected studies identified some major influences on seafood consumption, most of which have both positive and negative aspects and can thus function as both drivers and barriers (Fig. 2).

Sensory and taste preferences. Sensory and taste preferences were named as barriers to seafood consumption in fourteen studies. Seven of these papers specified that the barriers to fish consumption were to do with fish characteristics such as taste, smell or presence of bones[94–103]. Within elderly, problems with dentition were highlighted as a barrier to consumption, as it was reported to impact on one's ability to chew and bite[94]. Gastrointestinal issues following consumption of seafood also presented a barrier for some[104,105]. Unsurprisingly, a greater liking of the taste of fish was reported to drive consumption of fish[100,106,107].

Cost, convenience and availability. According to three studies[100,108,109], residing in locations with poor availability of seafood or fish presented a barrier to its consumption. For example, Hilger *et al.*[108] explored barriers to healthy eating

Table 1. Descriptions of studies that explored the barriers and drivers to seafood consumption

Author(s), year	Aim of the study	Sample size	Country	Population description	Barriers/drivers found
Altintzoglou *et al.*, 2011[129]	The aim of this study is to explore potential barriers to seafood consumption by young adults and the parents of young children	*n* 1319	Belgium, Norway, and Spain	55 % men. 18–55 years	Drivers: Health consciousness
Altintzoglou *et al.*, 2010[111]	To investigate the association of health involvement and attitudes towards eating fish on farmed and wild fish consumption in Belgium, Norway and Spain	*n* 28	Denmark, Norway, and Iceland	64·7 % women. 20–60 years	Barriers: Effort to prepare, price Drivers: Belief seafood is healthy and convenient
Appleton, 2016[106]	To investigate the barriers and facilitators to the consumption of protein-rich foods in older adults	*n* 351	UK	58 % women. Over 65 years	Drivers: Greater liking, education, health and nutritional issues that preparing fish is easy
Best & Appleton, 2013[94]	To explore the factors associated with the consumption of protein-rich foods in older adults	*n* 28	UK	96 % women. 65–93 years	Barriers: Sensory (taste, texture) and physical (teeth/dentures, mobility to shop and cook) challenges, living alone, low levels of education Drivers: Freshness, quality, belief in health value of the product
Birch & Lawley, 2012[103]	To explore the drivers and barriers to seafood consumption in Australia and to investigate attitudes towards pre-packaged fresh chilled seafood products	*n* 1815	Australia	72·9 % women. 18–55+ years	Barriers: Price, concerns about freshness, not liking the taste or texture of fish, convenience and ease of preparation Drivers: Health, taste, convenience, price
Birch *et al.*, 2012[101]	To explore the perceived risks of seafood consumption and how these vary across consumption levels	*n* 899	Australia	65·9 % women. 18–55+ years	Barriers: Convenience perception, household preferences and sensory issues
Bishop & Leblanc, 2017[104]	To compare DHA, EPA and fish intake of pregnant women at 30 weeks of gestation to current recommendations and to determine the factors associated with *n*-3 intake	*n* 54	Canada	Pregnant women. 20–40 years	Barriers: Lack of cooking inspiration, general dislike/taste preferences, gastrointestinal and sensory sensitivities due to pregnancy, cost, mercury contamination fears
Bostic *et al.*, 2017[100]	To examine rural New York State consumers' cognitive scripts for fish and seafood provisioning	*n* 31	USA	Men and women, 50–70 years	Barriers: Quality of fish available, availability at living location, cost, taste preferences Drivers: Taste preferences
Burger & Gochfield, 2009[120]	To investigate the perceptions of the risks and benefits of fish consumption	*n* 329	USA	82 % men. Mean age 46 years	Barriers: Fears over biotoxicity Drivers: Health perception
Clark *et al.*, 2011[113]	To understand factors promoting and reducing willingness and capacity to consume a healthy diet in people of low socio-economic status with CHD	*n* 28	Canada	61 % men, 45–88 years	Barriers: Cost
Connelly *et al.*, 2014[121]	To better understand what might be done to encourage women of childbearing age to eat healthy fish	*n* 857	USA	Women only, 18–45 years	Barriers: Pregnancy risk aversion
Dijkstra *et al.*, 2014[65]	To identify barriers for meeting the fruit, vegetable and fish guidelines in older Dutch adults, to investigate SES differences in these barriers, and to examine the mediating role of these barriers in the association between SES and adherence to these guidelines	*n* 1057	Netherlands	52·5 % women, 55–85 years	Barriers: Cost, habits/tradition, dietary preferences of household members, receiving unclear health advice, beliefs that fish spoils easily, beliefs that fish contains harmful materials

Table 1. (*Continued*)

Author(s), year	Aim of the study	Sample size	Country	Population description	Barriers/drivers found
Egolf *et al.*, 2018[105]	To examine the relationships between food disgust sensitivity and eating preferences, habits and behaviours as well as food waste frequency. Additionally, socio-demographic characteristics associated with food disgust sensitivity were examined	*n* 1181	Switzerland	42·2 % men, 20–80+ years	Barriers: How fish is prepared, higher level of food disgust towards fish, gastrointestinal issues
Forbes *et al.*, 2018[119]	To describe the dietary changes made during pregnancy, describe reasons for dietary changes and determine what changes aligned with recommendations	*n* 379	Canada	Women only. 18–43 years	Barriers: Belief that the food has a specific harmful contaminant Drivers: Belief that the food has a specific nutrient required for health
Gacek, 2014[131]	To analyse selected individual determinants of dietary choices, important for aetiology and prevention of degenerative cardiovascular disorders, in a group of menopausal women diagnosed with arterial hypertension	*n* 160	Poland	Women with arterial hypertension. 45–60 years	Drivers: Higher levels of self-efficacy, optimism and life satisfaction
Grieger *et al.*, 2012[95]	To explore the knowledge and barriers relating to fish consumption	*n* 854	Australia	55 % women. 51–75 years	Barriers: Cost, dislike of cooking fish or its smell, lack of knowledge of the current dietary recommendations for fish Drivers: Higher level of knowledge regarding the health benefits of fish
Hilger *et al.*, 2017[108]	To explore baseline dietary intake, common barriers to healthy eating and changes in eating behaviour among university students since the time of matriculation	*n* 689	Germany	30·5 % men, 16–29 years	Barriers: Lack of time, lack of choice at canteen, cost
Hinote *et al.*, 2009[114]	To examine the relationship between psychological distress and dietary consumption patterns in the former Soviet Union	*n* 18 428	Post-Soviet republics	Men and women >18 years	Barriers: Higher levels of mental distress, income level
Jacobs *et al.*, 2018[123]	To explore consumer response to health and environmental sustainability information regarding seafood consumption	*n* 986	Belgium and Portugal	Women 51 %, 18–70 years	Drivers: Belief that fish is healthy
Jovanović *et al.*, 2011[127]	To determine medical students' knowledge regarding the association between dietary factors and the risk of cancer and CVD and to investigate if this knowledge has an impact on their dietary intakes	*n* 390	Croatia	69 % women. Average age 22 years	Drivers: Better diet–disease knowledge positively correlated with higher intake of fish
Lando *et al.*, 2012[122]	To evaluate awareness of mercury as a problem in food and examined fish consumption levels among pregnant and postpartum women	*n* 3157	USA	Pregnant women over 18 years old in the third trimester of pregnancy. Control: women 18–40 years old	Barriers: Awareness that mercury consumption is harmful during pregnancy
Lawley *et al.*, 2012[102]	To explore the role and interplay of intrinsic and extrinsic cues when evaluating fish quality and in shaping consumers' attitudes towards fish consumption	*n* 145	Australia	66 % women	Barriers: Price, taste, texture

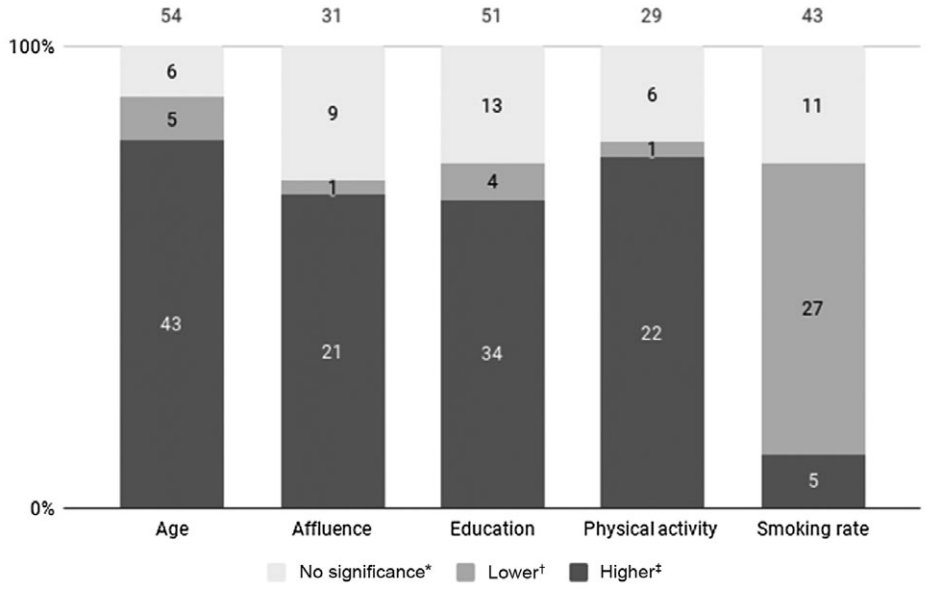
Table 1. (*Continued*)

Author(s), year	Aim of the study	Sample size	Country	Population description	Barriers/drivers found
Loose *et al.*, 2012[117]	To quantify effects of convenience and product packaging on consumer preferences and market share of seafood products: The case of oysters	*n* 1718	Australia	Survey respondents	Barriers: Preparation method, texture, price
Lucas *et al.*, 2016[96]	To explore pregnant women's perceptions of consuming fish and seafood during pregnancy	*n* 15	Australia	Pregnant women only	Barriers: Taste, cost, pregnancy risk aversion Drivers: Knowledge about the health benefits of fish
Neale *et al.*, 2012[97]	To investigate attitudes and perceptions influencing fish consumption in a sample of clinical trial participants and compare these perceptions to those expressed by a sample of adults not involved in the trial	*n* 29	USA	80 % women	Barriers: Belief that fish has a negative health impact, the cost of consuming fish and seafood products (both in terms of time and money), the physical and sensory characteristics of fish, food preferences of family members Drivers: Belief that fish has a positive health impact, convenience of canned fish, religious and cultural traditions
Olsen *et al.*, 2017[110]	To identify consumer segments based on the importance of product attributes when buying seafood for homemade meals on weekdays	*n* 840	Norway	47·9 % women, 18–80 years	Drivers: Availability of 'good' quality products, belief in the healthiness of seafood, nutritional value, value for money
Perez-Cueto *et al.*, 2011[124]	To identify attitudinal determinants of fish consumption in Spain and Poland, and to discuss the potential impact of local healthy eating policies in the observed reported frequency of fish consumption	*n* 1800	Spain and Poland	20–70 years	Drivers: Satisfaction with life, general attitude towards fish
Pieniak *et al.*, 2009[98]	To investigate consumer attitudes and behavioural patterns related to fish consumption in Poland and four Western European countries	*n* 4786	Europe	76·3 % women, over 18 years	Barriers: Cost, physical properties of fish (smell, bones) Drivers: Belief that fish is healthy and nutritious
Pieniak *et al.*, 2010[125]	To explore cultural differences in potential determinants of fish consumption: consumers' knowledge and health-related beliefs, as well as the relationship between those variables, socio-demographics and fish consumption frequency, using data from five European countries	*n* 4786	Belgium, Netherlands, Denmark, Poland and Spain	76·3 % women, 18–84 years	Drivers: Belief in the health benefits of fish, general interest in healthy eating
Pinho *et al.*, 2017[115]	To explore associations between various perceived barriers to healthy eating and dietary behaviours among adults from urban regions in five European countries and examine whether associations differed across regions and socio-demographic backgrounds	*n* 5900	Europe	55·9 % women, over 18 years	Barriers: Willpower, having a 'busy' lifestyle, price, household taste preferences

Table 1. (*Continued*)

Author(s), year	Aim of the study	Sample size	Country	Population description	Barriers/drivers found
Rahmawaty *et al.*, 2013[99]	To identify factors that influence the consumption of fish and foods that are enriched with *n*-3 LCPUFA, in order to inform the development of effective nutrition education strategies	*n* 262	Australia	35–44 years. Parents of young children	Barriers: Household taste preferences, personal taste preferences, price, preparation difficulties, characteristics of fish (bones, smell, pollutant content) Drivers: Belief in the health benefit of fish, healthy eating guidelines/advice from health professional, media influence, influences of household members and social group
Santos *et al.*, 2015[109]	To assess the changes in eating habits and food choice motives of Portuguese university students after migration to London, according to sex	*n* 55	UK	52·5 % women	Barriers: Migration and change to Western style diet traditionally lower in fish
Sapranaviciute-Zabazlajeva *et al.*, 2017[132]	To analyse the connection between psychological well-being and components of a healthy lifestyle	*n* 10 940	Lithuania	45–72 years	Drivers: Healthy psychological well-being
Scholderer & Trondsen, 2008[112]	To explore the dynamics of consumer behaviour on habit	*n* 4184	Norway	Women only born between 1951 and 1966	Barriers: Price Drivers: Quality
Skuland, 2015[126]	To investigate healthy eating and barriers related to social class	*n* 2000	Norway	15–79 years	Drivers: Higher education class
Sotos-Prieto *et al.*, 2014[116]	To assess the agreement between self-reported and parent-reported dietary and physical activity habits in children; and to evaluate the socio-economic determinants of healthier habits (Mediterranean diet and physical activity) among children	*n* 2062	Spain	Children 3–5 years and their parents	Barriers: Parental dietary habits, lower parental income and education Drivers: Parental dietary habits
Stimming *et al.*, 2015[128]	To assess the consumption habits of fish and rapeseed oil and their determining factors in 985 mother–child dyads in Germany	*n* 985 Mother–child dyads	Germany	Women only. 18–50 years	Drivers: Mothers with higher *n*-3 knowledge were associated with a high maternal fish consumption
Sveinsdottir *et al.*, 2009[107]	To explore the sensory characteristics of different cod products related to consumer preferences and attitudes	*n* 378	Europe	Consumers from 4 European countries	Barriers: Price Drivers: Household preferences, health involvement, liking fish
Tiainen *et al.*, 2013[130]	To explore the associations between food and nutrient intake, personality traits and resilience	*n* 1681	Finland	44 % men. Mean age 61·5 years	Barriers: Higher levels of neuroticism Drivers: Higher levels of resilience
Tomić *et al.*, 2016[118]	To determine the factors influencing fresh fish consumption using an expanded Theory of Planned Behaviour (Ajzen, 1991) as a theoretical framework	*n* 1151	Croatia	70 % F. 18–60+ years	Drivers: Personal health involvement, influence of the subjective norm, feelings of moral obligation

SES, socio-economic status; LCPUFA, long-chain PUFA.



*Number of papers that found no significant association between the characteristic and seafood consumption.
†Number of papers that found seafood consumption was associated with lower age/affluence/educational level/physical activity level/smoking rate.
‡Number of papers that found seafood consumption was associated with higher age/affluence/educational level/physical activity level/smoking rate.

Fig. 2. Number of papers examining the association between the demographic and social characteristics of seafood consumption.

specifically in college students and found that lack of availability or lack of choice of fish and seafood in the canteen was a barrier to consumption of these products for students. Santos *et al.*[109] also looked at eating habits of university students; however, this sample size only focused on Portuguese students post-migration to the UK. This paper noted that migration to a country with lower reported fish consumption caused a significant decrease in these student's fish consumption. Lack of access and availability were also noted in elderly cohort, where the impact of physical impairments such as reduced mobility or disability was highlighted as a barrier to the consumption for elderly people[94]. Convenience in relation to preparing and consuming seafood was also highlighted as a barrier in five studies[94,101,103,110,111].

In addition, a lack of 'good quality' seafood was also reported as a barrier to its purchase and consumption[100,101,112]. Living in a location where fresh and 'good quality' seafood was available positively influenced people to consume it, which was reported in two papers[94,100]. Cost of seafood was a commonly reported barrier to consumption and was mentioned in nineteen studies[65,95–102,104,107,108,111–117]. Sotos-Prieto *et al.*[116] specified that those with low income were less likely to consume fish regularly. However, three papers found that providing good value for money (i.e. special offers in stores) had a positive influence on seafood consumption[100,110,112].

Knowledge of storage, handling and cooking. Three studies highlighted that lack of skills, particularly cooking skills, can be barriers to seafood consumption[99,104,111]. Bishop & Leblanc[104] and Rahmawaty *et al.*[99] reported that people who lacked cooking knowledge and inspiration found it difficult to find the motivation to cook seafood for themselves and their household. Dijkstra *et al.*[65] also found that holding the belief that fish spoils easily is a barrier to its consumption. Believing that fish is a convenient food and is easy to prepare was highlighted as a positive influence on its consumption in two studies[97,106].

Familial, lifestyle and cultural environment. Six studies[65,97,99,107,115,116] found that the dietary preferences of household members were an influence to seafood consumption. Low- or non-fish consumers were more likely to view the taste preferences of household members as a negative influence on frequency of seafood consumption[99]. A busy lifestyle was also noted as a barrier by Pinho *et al.*[115]. Four papers found various environmental influences can drive seafood consumption. Neale *et al.*[97] stated that religious and cultural traditions, as well as parental attitudes, can be positive influences on seafood consumption if they encourage the same. Participants in Rahmawaty's *et al.*[99] study mentioned that professionals, media, household and society can be positive influences on their seafood consumption. Parental dietary habits strongly influence seafood consumption in their children[116]. Subjective norm and feelings of moral obligation can also positively influence seafood consumption; therefore, this can act as both a barrier and a driver of seafood consumption depending on the situation[118].

Health and nutritional beliefs. Holding certain health and nutritional beliefs about seafood can influence whether or not the person chooses to consume seafood. For example, the perception that fish and seafood may contain harmful contaminants was seen as a barrier in five papers[65,97,104,119,120]. Three

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papers[96,121,122] found avoidance of fish, due to the belief that it is harmful, was a common barrier during pregnancy. Perceiving seafood to have a high 'health' value, or believing it contains certain nutrients needed for good health, is a commonly reported positive driver of its consumption[94–99,101,107,110,111,117–120,123–129].

Psychological traits. A small number of papers (*n* 3) found that having certain psychological traits may present barriers to consuming seafood. Having high levels of distress[114] and neuroticism[130], and low willpower[115] were highlighted as possible barriers to seafood consumption. Four papers explored the influence of various psychological states and personality traits on seafood consumption and noted that having high levels of self-efficacy, optimism, life satisfaction, resilience and a general healthy psychological well-being positively influenced seafood consumption[124,130–132].

Discussion

The results of this systematic review highlight that seafood consumers were more likely to be older, more affluent (in terms of income, employment level and/or socio-economic status), educated and physically active and were less likely to smoke compared with non-seafood consumers. Sex and BMI did not appear to have a clear influence on seafood consumption. The findings also suggest that the most commonly reported influences on seafood consumption relate to personal preference, availability, cost, cooking skills and knowledge, environment, health and nutritional beliefs and psychological traits. The most commonly reported barrier to seafood consumption was price. Other barriers included the sensory or physical characteristics of seafood, household preferences, health and nutritional beliefs (e.g. that fish contains harmful contaminants), environmental barriers, lack of cooking skills and negative psychological states/personality traits. The most commonly reported drivers of seafood consumption were perceived health benefits of seafood, environmental influences (e.g. family, friends and social norm), availability of fresh seafood, positive psychological states or personality traits and personal preferences. These barriers and drivers agree with certain common characteristics that seafood consumers seem to share.

Cost was the most commonly reported barrier to seafood consumption[95–100,104,108,115,133]. This is a particularly important barrier for people who have a lower income level[114,116]. Food prices play a major role in diet quality and food choice[77]. Although seafood has become more widely available, depending on the country, the fish species, and the presentation or format of sale, it can be a costly item compared with other high protein foods[134,135]. This is in line with our findings, as those who consumed the highest amounts of seafood tended to have higher incomes, as well as be of older age, which agrees with the general trend of income increasing with age as a person gain experience over time[136]. In addition, as individuals age, increased risk of health issues such as cognitive decline and CVD can influence food choice, including that of seafood, known to be rich in nutrients beneficial to health[137,138], with the perceived cost benefit changing as one ages. Unsurprisingly, cost was also highlighted as a barrier to healthy eating for university students[108]. Interventions carried out in the UK[139] and the USA[140] which trialled providing vouchers for the purchase of healthy foods, such as fruits and vegetables or seafood, have been found to be a simple and effective way of encouraging people to purchase these products. Interestingly, the provision of these vouchers was more effective than dietary advice alone. Other reviews found that pricing interventions generally increased the consumption and purchase of promoted foods[141–143].

Our findings suggest that those who achieve a higher level of education are more likely to be seafood consumers. Having a higher degree of education may result in better knowledge and understanding of current healthy eating recommendations for fish[77,144]. Education may also be associated with increased nutritional knowledge in general and the ability to translate this knowledge into healthy dietary practice[145]. However, education level does not directly determine level of seafood consumption as evidenced by population groups that eat fish traditionally, but have generally low rates of formal education[146]. Belief that fish is healthy and contains important nutrients for health is often reported as a major influence on seafood consumption, regardless of education level[94–99,110,118,119,123–125]. The most commonly reported barrier was the belief that fish or seafood may contain harmful contaminants[97,99,104,119,133] or that fish/seafood is harmful during pregnancy, with particular concern about its mercury content[96,121,122]. Education regarding true contamination levels in various fish and seafood species, as well as guidelines for fish consumption during pregnancy, may be paramount to overcoming these barriers, and information received from healthcare professionals need to be clear[133]. Those who are in greater agreement that fish should be fresh, that it is easy to prepare, is convenient and disagreement that fish spoils easily are more likely to consume it[97,106]. However, interventions aiming to improve diet quality or intakes of certain food groups through nutrition education alone have had mixed results, suggesting a combination of methods including education may be needed to improve diets[123,147–152].

Gaining knowledge about the health benefits of seafood may help overcome barriers such as nutritional and health beliefs, or habits arising from an individual's Familial, Lifestyle and Cultural Environment. However, it is also important to know that may be less effective in overcoming barriers such as taste. Having a dislike of the taste and/or smell of fish[94–100,104], as well as a dislike of its texture, is a commonly reported barrier to seafood consumption in general[97,98]. In particular, pregnant women seem to have a high level of food disgust or gastrointestinal issues related to seafood consumption[104,105]. Changes that come with old age, such as chemosensory loss, can lead to reduced enjoyment of the taste of seafood[94]. Physical impairments that reduce the convenience of cooking or purchasing foods present an important barrier to seafood consumption in the elderly[94,99]. Some of these barriers are personal preferences and therefore are difficult to overcome; however, in regards to taste changes, adding natural food flavours has been used in an attempt to increase food and nutrient intakes in the elderly with some success[153]. Previous research has also shown that participants who disliked the taste of fish or seafood, but who were aware of its

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health benefits, attempted to overcome this taste preference barriers by experimenting with various cooking methods and seafood products[96]. However, knowing the benefits of seafood alone may not be enough to initiate its purchase and consumption due to time constraints for cooking as well as affordability[77]. Physical impairments to cooking and food shopping may be overcome by organising meal delivery to the persons home, which have been shown to increase diet quality and nutrient intakes among the elderly[154,155]. However, this may not be appropriate for everyone, such as patients with behavioural and cognitive impairments[156].

Good local availability of fresh, or what consumers deem good quality seafood, or lack thereof, seems to influence intent to purchase what actually is on offer[94,100,108,109]. Availability of seafood in an individual's living location, or where they tend to purchase their meals, influences whether or not they consume it[100,108,109]. The purchasing behaviour can concern overall availability of seafood in general but may also be influenced by the type of seafood available. According to Bord Bia[135], fish represented 2 % of the Irish grocery spent in 2018 and the large majority of this was fresh fish. Frozen fish sales decreased compared with previous years, partially due to a decrease in shoppers' willingness to buy frozen fish. This seems to highlight a preference for fresh fish over frozen. Therefore, if fresh fish is not available, the consumption of seafood may decrease due to the consumer's unwillingness to purchase frozen alternatives that are available. Food availability is also related to affluence[77]. Analyses show that supermarkets tend to cluster in more affluent areas and that 'food deserts' are common within lower socio-economic status neighbourhoods[77]. Studies have also shown that residing in lower-income neighbourhoods has been associated with lower consumption of fish[157] and that a person's level of income and occupation is a significant determinant of fish consumption[158].

This study has identified multiple barriers to seafood consumption which need to be overcome in order to increase seafood intake. Methods to help people overcome these barriers include pricing interventions, such as the provision of food vouchers or in-store discounts or value offers[139–143]. In addition to this, interventions may need to focus on increasing nutritional knowledge and awareness through school-based[151] and adult[159] educational programmes as well as environmental sustainability education[123]. However, the most promising results are seen when interventions tackle multiple or most of the aforementioned barriers to consumption[150,159]. This means combining individual education (which should combine nutrition theory and practice, i.e. cooking skills) from school level through to senior years with structural environmental changes, such as improving access to supermarkets[77] and making healthy foods such as seafood more affordable[139], particularly for people on lower incomes. Future interventions aiming to increase seafood consumption, or diet quality overall, should therefore take on a multi-faceted approach, as seen in the Community Intervention to Increase Seafood Consumption Project carried out in Australia[160]. Any interventions seeking to promote seafood consumption should be carried out with consideration of biotoxicity risk[6,7]. In addition, recommendations should also take into account sustainability targets, such as those set out in the EAT-Lancet report which recommend a maximum of about 100 g of fish/d[5].

Limitations

It is important to note that, in cross-sectional studies, any solitary associations are not evidence of causality. The determinants of food choice are complex and cannot be attributed to only one single reason. Overall, conclusions should be drawn with caution owing to the small number of studies for each specific influence–intake association. Limitations of this study include that the findings of this review are limited to published papers only (unpublished results or additional reports were not included), in English, between 2008 and 2019. This is also one of the first systematic reviews published on the determinants of seafood consumption. Although it is a systematic review, meta-analysis was not carried out; therefore, sample size was not considered. Additionally, categorisation of findings was subjective however was decided on once consensus that was reached among authors following discussion.

Conclusions

This review has highlighted two key aspects of importance for the development of effective public health campaigns aiming to increase consumption of seafood. It firstly determined demographic factors influencing consumption of seafood, thus outlining which population groups could be targeted. It then secondly outlined evidence of the reported reasons influencing seafood consumption, outlining areas for potential intervention including nutritional education, development of cooking skills, pricing and availability amongst others. The evidence presented demonstrates that specific population groups such as those of a younger age and those less educated would benefit most from interventions, information which would allow the development of targeted and appropriately designed interventions, which could focus on aspects specifically influencing intakes in each of these population groups. More research is needed to explore the effectiveness of specific interventions in increasing the consumption of seafood.

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Supplementary material

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References

1. Nesheim M, Oria M & Yih P (2015) *A Framework for Assessing Effects of the Food System*, 1st ed. Washington, DC: National Academies Press.
2. Safefood (2019) The benefits of eating fish. https://www.safefood.eu/Healthy-Eating/Food,-Diet-and-Health/Eating-In/The-benefits-of-eating-fish.aspx2019 (accessed October 2019).
3. National Institutes of Health (NIH) (2020) Iodine – consumer. https://ods.od.nih.gov/factsheets/Iodine-Consumer/ (accessed July 2020).
4. Troell M, Jonell M & Crona B (2019) *Scoping Report: The Role of Seafood in Sustainable and Healthy Diets. The EAT-Lancet Commission Report Through a Blue Lens.* Stockholm: Stockholm Resilience Centre.
5. Willett W, Rockstrom J, Loken B, *et al.* (2019) Food in the anthropocene: the EAT-Lancet Commission on healthy diets from sustainable food systems. *Lancet* **393**, 447–492.
6. Sirot V, Leblanc JC & Margaritis I (2012) A risk-benefit analysis approach to seafood intake to determine optimal consumption. *Br J Nutr* **107**, 1812–1822.
7. Hellberg R, DeWitt C & Morrissey M (2012) Risk-benefit analysis of seafood consumption: a review. *Compr Rev Food Sci Food Saf* **11**, 490–517.
8. European Commission (2019) Mercury – mercury in food. https://ec.europa.eu/food/safety/chemical_safety/contaminants/catalogue/mercury_en (accessed October 2019).
9. Irish Universities Nutrition Alliance (IUNA) (2011) National Adult Nutrition Survey. https://irp-cdn.multiscreensite.com/46a7ad27/files/uploaded/The%20National%20Adult%20Nutrition%20Survey%20Summary%20Report%20March%202011.pdf 11. (2017) 6. Consumption. Food, Farming, Fisheries. (accessed 21/11/19 2019)
10. European Commission (2017) Fisheries – consumption. https://ec.europa.eu/fisheries/6-consumption_en (accessed October 2019).
11. Barilla Center for Food and Nutrition (2019) The rise of plant-based diets gathers momentum. https://foodsustainability.eiu.com/rise-plant-based-diets-gathers-momentum/ (accessed January 2020).
12. Buscemi S, Nicolucci A, Lucisano G, *et al.* (2014) Habitual fish intake and clinically silent carotid atherosclerosis. *Nutr J* **13**, 2.
13. Akbaraly TN & Brunner EJ (2008) Socio-demographic influences on trends of fish consumption during later adult life in the Whitehall II study. *Br J Nutr* **100**, 1116–1127.
14. Anderson JS, Nettleton JA, Herrington DM, *et al.* (2010) Relation of omega-3 fatty acid and dietary fish intake with brachial artery flow-mediated vasodilation in the Multi-Ethnic Study of Atherosclerosis. *Am J Clin Nutr* **92**, 1204–1213.
15. Heppe DH, Steegers EA, Timmermans S, *et al.* (2011) Maternal fish consumption, fetal growth and the risks of neonatal complications: the Generation R Study. *Br J Nutr* **105**, 938–949.
16. Hostenkamp G & Sørensen J (2010) Are fish eaters healthier and do they consume less health-care resources? *Public Health Nutr* **13**, 453–460.
17. Inelmen EM, Toffanello ED, Enzi G, *et al.* (2008) Differences in dietary patterns between older and younger obese and overweight outpatients. *J Nutr Health Aging* **12**, 3–8.
18. Jahns L, Raatz SK, Johnson LK, *et al.* (2014) Intake of seafood in the US varies by age, income, and education level but not by race-ethnicity. *Nutrients* **6**, 6060–6075.
19. Kossioni A & Bellou O (2011) Eating habits in older people in Greece: the role of age, dental status and chewing difficulties. *Arch Gerontol Geriatr* **52**, 197–201.
20. Larsson SC & Wolk A (2010) Fish, long-chain omega-3 polyunsaturated fatty acid intake and incidence of atrial fibrillation: A pooled analysis of two prospective studies. *Clin Nutr* **36**, 537–541.
21. Levitan EB, Wolk A & Mittleman MA (2010) Fatty fish, marine omega-3 fatty acids and incidence of heart failure. *Eur J Clin Nutr* **64**, 587–594.
22. Marushka L, Batal M, Sadik T, *et al.* (2018) Seafood consumption patterns, their nutritional benefits and associated socio-demographic and lifestyle factors among First Nations in British Columbia, Canada. *Public Health Nutr* **21**, 3223–3236.
23. Mohanty AF, Siscovick DS, Williams MA, *et al.* (2016) Periconceptional seafood intake and pregnancy complications. *Public Health Nutr* **19**, 1795–1803.
24. Monastero R, Karimi R, Silbernagel S, *et al.* (2016) Demographic profiles, mercury, selenium, and omega-3 fatty acids in avid seafood consumers on Long Island, NY. *J Community Health* **41**, 165–173.
25. Mullie P, Guelinckx I, Clarys P, *et al.* (2009) Cultural, socioeconomic and nutritional determinants of functional food consumption patterns. *Eur J Clin Nutr* **63**, 1290–1296.
26. Razzaghi H & Tinker SC (2014) Seafood consumption among pregnant and non-pregnant women of childbearing age in the United States, NHANES 1999–2006. *Food Nutr Res* **58**, 10.3402/fnr.v58.23287.
27. Strøm M, Halldorsson TI, Mortensen EL, *et al.* (2012) Fish, *n*-3 fatty acids, and cardiovascular diseases in women of reproductive age: a prospective study in a large national cohort. *Hypertension* **59**, 36–43.
28. Wallin A, Di Giuseppe D, Orsini N, *et al.* (2017) Fish consumption and frying of fish in relation to type 2 diabetes incidence: a prospective cohort study of Swedish men. *Eur J Nutr* **56**, 843–852.
29. Touvier M, Kesse-Guyot E, Mejean C, *et al.* (2010) Variations in compliance with recommendations and types of meat/seafood/eggs according to sociodemographic and socioeconomic categories. *Ann Nutr Metab* **56**, 65–73.
30. Stravik M, Jonsson K, Hartvigsson O, *et al.* (2019) Food and nutrient intake during pregnancy in relation to maternal characteristics: results from the NICE Birth Cohort in Northern Sweden. *Nutrients* **11**, 1680.
31. Christensen KY, Raymond M, Blackowicz M, *et al.* (2017) Perfluoroalkyl substances and fish consumption. *Environ Res* **154**, 145–151.
32. Clonan A, Holdsworth M, Swift JA, *et al.* (2012) The dilemma of healthy eating and environmental sustainability: the case of fish. *Public Health Nutr* **15**, 277–284.
33. Hansen-Krone IJ, Enga KF, Südduth-Klinger JM, *et al.* (2014) High fish plus fish oil intake is associated with slightly reduced risk of venous thromboembolism: the Tromsø Study. *J Nutr* **144**, 861–867.
34. Patel PS, Sharp SJ, Luben RN, *et al.* (2009) Association between type of dietary fish and seafood intake and the risk of incident type 2 diabetes: the European prospective investigation of cancer (EPIC)-Norfolk cohort study. *Diabetes Care* **32**, 1857–1863.
35. Picot C, Thuan AN, Carpentier FG, *et al.* (2011) Relevant shellfish consumption data for dietary exposure assessment among high shellfish consumers, Western Brittany, France. *Int J Environ Health Res* **21**, 86–105.

36. Zamora-Ros R, Castañeda J, Rinaldi S, *et al.* (2017) Consumption of fish is not associated with risk of differentiated thyroid carcinoma in the European Prospective Investigation into Cancer and Nutrition (EPIC) Study. *J Nutr* **147**, 1366–1373.
37. Nahab F, Pearson K, Frankel MR, *et al.* (2016) Dietary fried fish intake increases risk of CVD: the REasons for Geographic And Racial Differences in Stroke (REGARDS) study. *Public Health Nutr* **19**, 3327–3336.
38. Brasky TM, Neuhouser ML, Cohn DE, *et al.* (2014) Associations of long-chain ω-3 fatty acids and fish intake with endometrial cancer risk in the VITamins And Lifestyle cohort. *Am J Clin Nutr* **99**, 599–608.
39. Torris C, Smastuen MC & Molin M (2018) Nutrients in fish and possible associations with cardiovascular disease risk factors in metabolic syndrome. *Nutrients* **10**, 952.
40. Langlois K & Ratnayake WMN (2015) Omega-3 index of Canadian adults. *Health Rep* **26**, 3–11.
41. Gale CR, Robinson SM, Godfrey KM, *et al.* (2008) Oily fish intake during pregnancy – association with lower hyperactivity but not with higher full-scale IQ in offspring. *J Child Psychol Psychiatry* **49**, 1061–1068.
42. Lee CC, Howard BV, Mete M, *et al.* (2012) Association between fish consumption and nephropathy in American Indians–the Strong Heart Study. *J Ren Nutr* **22**, 221–227.
43. Karlsson T, Rosendahl-Riise H, Dierkes J, *et al.* (2017) Associations between fish intake and the metabolic syndrome and its components among middle-aged men and women: the Hordaland Health Study. *Food Nutr Res* **61**, 1347479.
44. Gaskins AJ, Sundaram R, Buck Louis GM, *et al.* (2018) Seafood intake, sexual activity, and time to pregnancy. *J Clin Endocrinol Metab* **103**, 2680–2688.
45. Burger J (2008) Fishing, fish consumption, and awareness about warnings in a university community in central New Jersey in 2007, and comparisons with 2004. *Environ Res* **108**, 107–116.
46. Pfeiler TM & Egloff B (2018) Personality and meat consumption: the importance of differentiating between type of meat. *Appetite* **130**, 11–19.
47. Crowe FL, Skeaff CM, Green TJ, *et al.* (2008) Serum *n*-3 long-chain PUFA differ by sex and age in a population-based survey of New Zealand adolescents and adults. *Br J Nutr* **99**, 168–174.
48. Pavlović M, Milković-Kraus S, Jovanović V, *et al.* (2012) Ageing, arterial blood pressure, body mass index, and diet. *Arh Hig Rada Toksikol* **63**, Suppl. 1, 3–9.
49. Salas R, del Mar Bibiloni M, Zapata ME, *et al.* (2013) Balearic adults have low intakes of fruits and vegetables compared with the dietary guidelines for adults in Spain. *Nutr Res* **33**, 204–210.
50. Sioen I, Vyncke K, De Maeyer M, *et al.* (2013) Dietary intake and food sources of total and individual polyunsaturated fatty acids in the Belgian population over 15 years old. *Lipids* **48**, 729–738.
51. Belle F, Wengenroth L, Weiss A, *et al.* (2017) Low adherence to dietary recommendations in adult childhood cancer survivors. *Clin Nutr* **36**, 1266–1274.
52. Kim YS, Xun P, Iribarren C, *et al.* (2016) Intake of fish and long-chain omega-3 polyunsaturated fatty acids and incidence of metabolic syndrome among American young adults: a 25-year follow-up study. *Eur J Nutr* **55**, 1707–1716.
53. Li J, Xun P, Zamora D, *et al.* (2013) Intakes of long-chain omega-3 (*n*-3) PUFAs and fish in relation to incidence of asthma among American young adults: the CARDIA study. *Am J Clin Nutr* **97**, 173–178.
54. Virtanen JK, Mozaffarian D, Cauley JA, *et al.* (2010) Fish consumption, bone mineral density, and risk of hip fracture among older adults: the cardiovascular health study. *J Bone Miner Res* **25**, 1972–1979.
55. Mozaffarian D, Stein PK, Prineas RJ, *et al.* (2008) Dietary fish and omega-3 fatty acid consumption and heart rate variability in US adults. *Circulation* **117**, 1130–1137.
56. Bonaccio M, Ruggiero E, Di Castelnuovo A, *et al.* (2017) Fish intake is associated with lower cardiovascular risk in a Mediterranean population: prospective results from the Moli-sani study. *Nutr Metab Cardiovasc Dis* **27**, 865–873.
57. Belin RJ, Greenland P, Martin L, *et al.* (2011) Fish intake and the risk of incident heart failure: the Women's Health Initiative. *Circ Heart Fail* **4**, 404–413.
58. van Woudenbergh GJ, van Ballegooijen AJ, Kuijsten A, *et al.* (2009) Eating fish and risk of type 2 diabetes: a population-based, prospective follow-up study. *Diabetes Care* **32**, 2021–2026.
59. Giuli C, Papa R, Mocchegiani E, *et al.* (2012) Dietary habits and ageing in a sample of Italian older people. *J Nutr Health Aging* **16**, 875–879.
60. Papier K, Ahmed F, Lee P, *et al.* (2015) Stress and dietary behaviour among first-year university students in Australia: sex differences. *Nutrition* **31**, 324–330.
61. Johansson J, Hult A, Morseth B, *et al.* (2018) Self-reported protein intake and properties of bone in community-dwelling older individuals. *Arch Osteoporos* **13**, 10.
62. Lake AA, Adamson AJ, Craigie AM, *et al.* (2009) Tracking of dietary intake and factors associated with dietary change from early adolescence to adulthood: the ASH30 study. *Obes Facts* **2**, 157–165.
63. He K, Liu K, Daviglus ML, *et al.* (2009) Associations of dietary long-chain *n*-3 polyunsaturated fatty acids and fish with biomarkers of inflammation and endothelial activation (from the Multi-Ethnic Study of Atherosclerosis [MESA]). *Am J Cardiol* **103**, 1238–1243.
64. Chung H, Nettleton JA, Lemaitre RN, *et al.* (2008) Frequency and type of seafood consumed influence plasma (*n*-3) fatty acid concentrations. *J Nutr* **138**, 2422–2427.
65. Dijkstra SC, Neter JE, Brouwer IA, *et al.* (2014) Adherence to dietary guidelines for fruit, vegetables and fish among older Dutch adults; the role of education, income and job prestige. *J Nutr Health Aging* **18**, 115–121.
66. Meier M, Berchtold A, Akré C, *et al.* (2010) Who eats healthily? A population-based study among young Swiss residents. *Public Health Nutr* **13**, 2068–2075.
67. Sala-Vila A, Harris WS, Cofán M, *et al.* (2011) Determinants of the omega-3 index in a Mediterranean population at increased risk for CHD. *Br J Nutr* **106**, 425–431.
68. Alkerwi A, Sauvageot N, Buckley JD, *et al.* (2015) The potential impact of animal protein intake on global and abdominal obesity: evidence from the Observation of Cardiovascular Risk Factors in Luxembourg (ORISCAV-LUX) study. *Public Health Nutr* **18**, 1831–1838.
69. Miura K, Giskes K & Turrell G (2012) Socio-economic differences in takeaway food consumption among adults. *Public Health Nutr* **15**, 218–226.
70. Mendez MA, Plana E, Guxens M, *et al.* (2010) Seafood consumption in pregnancy and infant size at birth: results from a prospective Spanish cohort. *J Epidemiol Community Health* **64**, 216–222.
71. Maguire ER & Monsivais P (2015) Socio-economic dietary inequalities in UK adults: an updated picture of key food groups and nutrients from national surveillance data. *Br J Nutr* **113**, 181–189.
72. Barton KL, Wrieden WL, Sherriff A, *et al.* (2015) Trends in socio-economic inequalities in the Scottish diet: 2001–2009. *Public Health Nutr* **18**, 2970–2980.

British Journal of Nutrition

73. Li Y, Dai Q, Ekperi LI, *et al.* (2011) Fish consumption, severely depressed mood, findings from the first national nutrition follow-up study. *Psychiatry Res* **190**, 103–109.
74. McCartney DM, Younger KM, Walsh J, *et al.* (2013) Socio-economic differences in food group and nutrient intakes among young women in Ireland. *Br J Nutr* **110**, 2084–2097.
75. Nair A, Jordan M, Watkins S, *et al.* (2014) Fish consumption and hair mercury levels in women of childbearing age, Martin County, Florida. *Matern Child Health J* **18**, 2352–2361.
76. Seiluri T, Lahelma E, Rahkonen O, *et al.* (2011) Changes in socio-economic differences in food habits over time. *Public Health Nutr* **14**, 1919–1926.
77. Darmon N & Drewnowski A (2008) Does social class predict diet quality? *Am J Clin Nutr* **87**, 1107–1117.
78. Haggarty P, Campbell D, Duthie S, *et al.* (2009) Diet, deprivation in pregnancy. *Br J Nutr* **102**, 1487–1497.
79. Watt HC, Carson C, Lawlor DA, *et al.* (2009) Influence of life course socioeconomic position on older women's health behaviors: findings from the British Women's Heart, Health Study. *Am J Public Health* **99**, 320–327.
80. Larsson SC, Virtamo J & Wolk A (2011) Fish consumption and risk of stroke in Swedish women. *Am J Clin Nutr* **93**, 487–493.
81. Nordgren TM, Lyden E, Anderson-Berry A, *et al.* (2017) Omega-3 fatty acid intake of pregnant women and women of childbearing age in the United States: potential for deficiency? *Nutrients* **9**, 197.
82. Lê J, Dallongeville J, Wagner A, *et al.* (2013) Attitudes toward healthy eating: a mediator of the educational level-diet relationship. *Eur J Clin Nutr* **67**, 808–814.
83. Slagter SN, Corpeleijn E, van der Klauw MM, *et al.* (2018) Dietary patterns and physical activity in the metabolically (un)healthy obese: the Dutch Lifelines cohort study. *Nutr J* **17**, 18.
84. Wennberg M, Tornevi A, Johansson I, *et al.* (2012) Diet and lifestyle factors associated with fish consumption in men and women: a study of whether gender differences can result in gender-specific confounding. *Nutr J* **11**, 101.
85. Haraldsdottir A, Steingrimsdottir L, Valdimarsdottir UA, *et al.* (2017) Early life residence, fish consumption, and risk of breast cancer. *Cancer Epidemiol Biomarkers Prev* **26**, 346–354.
86. Virtanen JK, Mozaffarian D, Chiuve SE, *et al.* (2008) Fish consumption and risk of major chronic disease in men. *Am J Clin Nutr* **88**, 1618–1625.
87. Rosendahl-Riise H, Sulo G, Karlsson T, *et al.* (2018) The limited benefit of fish consumption on risk of hip fracture among men in the Community-Based Hordaland Health Study. *Nutrients* **10**, 873.
88. Chavarro JE, Stampfer MJ, Hall MN, *et al.* (2008) A 22-y prospective study of fish intake in relation to prostate cancer incidence and mortality. *Am J Clin Nutr* **88**, 1297–1303.
89. Song M, Chan AT, Fuchs CS, *et al.* (2014) Dietary intake of fish, ω-3 and ω-6 fatty acids and risk of colorectal cancer: a prospective study in U.S. men and women. *Int J Cancer* **135**, 2413–2423.
90. Varraso R, Barr RG, Willett WC, *et al.* (2015) Fish intake and risk of chronic obstructive pulmonary disease in 2 large US cohorts. *Am J Clin Nutr* **101**, 354–361.
91. Scaglia N, Chatkin J, Chapman KR, *et al.* (2016) The relationship between omega-3 and smoking habit: a cross-sectional study. *Lipids Health Dis* **15**, 61.
92. Smith KM, Barraj LM, Kantor M, *et al.* (2009) Relationship between fish intake, *n*-3 fatty acids, mercury and risk markers of CHD (National Health and Nutrition Examination Survey 1999–2002). *Public Health Nutr* **12**, 1261–1269.
93. Karlsson T, Strand E, Dierkes J, *et al.* (2017) Associations between intake of fish and *n*-3 long-chain polyunsaturated fatty acids and plasma metabolites related to the kynurenine pathway in patients with coronary artery disease. *Eur J Nutr* **56**, 261–272.
94. Best RL & Appleton KM (2013) The consumption of protein-rich foods in older adults: an exploratory focus group study. *J Nutr Educ Behav* **45**, 751–755.
95. Grieger JA, Miller M & Cobiac L (2012) Knowledge and barriers relating to fish consumption in older Australians. *Appetite* **59**, 456–463.
96. Lucas C, Starling P, McMahon A, *et al.* (2016) Erring on the side of caution: pregnant women's perceptions of consuming fish in a risk averse society. *J Hum Nutr Diet* **29**, 418–426.
97. Neale EP, Nolan-Clark D, Probst YC, *et al.* (2012) Comparing attitudes to fish consumption between clinical trial participants and non-trial individuals. *Nutr Diet* **69**, 124–129.
98. Pieniak Z, Verbeke W, Brunso K, *et al.* (2009) Comparison between polish, western European fish consumers in their attitudinal, behavioural patterns. *Acta Aliment* **38**, 179–192.
99. Rahmawaty S, Charlton K, Lyons-Wall P, *et al.* (2013) Factors that influence consumption of fish and omega-3-enriched foods: a survey of Australian families with young children. *Nutr Diet* **70**, 286–293.
100. Bostic SM, Sobal J, Bisogni CA, *et al.* (2017) Types and characteristics of fish and seafood provisioning scripts used by rural midlife adults. *J Nutr Educ Behav* **49**, 535–544.e1.
101. Birch D, Lawley M & Hamblin D (2012) Drivers and barriers to seafood consumption in Australia. *J Consum Mark* **29**, 64–73.
102. Lawley M, Birch D & Hamblin D (2012) An exploratory study into the role and interplay of intrinsic and extrinsic cues in Australian consumers' evaluations of fish. *Australas Mark J* **20**, 260–267.
103. Birch D & Lawley M (2012) Buying seafood: understanding barriers to purchase across consumption segments. *Food Qual Prefer* **26**, 12–21.
104. Bishop N & Leblanc C (2017) Dietary intake of DHA and EPA in a group of pregnant women in the Moncton area. *Can J Diet Pract Res* **78**, 59–65.
105. Egolf A, Siegrist M & Hartmann C (2018) How people's food disgust sensitivity shapes their eating and food behaviour. *Appetite* **127**, 28–36.
106. Appleton K (2016) Barriers to and facilitators of the consumption of animal-based protein-rich foods in older adults. *Nutrients* **8**, 187.
107. Sveinsdottir K, Martinsdottir E, Green-Petersen D, *et al.* (2009) Sensory characteristics of different cod products related to consumer preferences and attitudes. *Food Qual Prefer* **20**, 120–132.
108. Hilger J, Loerbroks A & Diehl K (2017) Eating behaviour of university students in Germany: dietary intake, barriers to healthy eating and changes in eating behaviour since the time of matriculation. *Appetite* **109**, 100–107.
109. Santos S, Vilela S, Padrao P, *et al.* (2015) Sex-related dietary changes of Portuguese university students after migration to London, UK. *Nutr Diet* **72**, 340–346.
110. Olsen S, Tuu H & Grunert K (2017) Attribute importance segmentation of Norwegian seafood consumers: the inclusion of salient packaging attributes. *Appetite* **117**, 214–223.
111. Altintzoglou T, Birch Hansen K, Valsdottir T, *et al.* (2010) Translating barriers into potential improvements: the case of new healthy seafood product development. *J Consum Mark* **27**, 224–235.
112. Scholderer J & Trondsen T (2008) The dynamics of consumer behaviour on habit, discontent, and other fish to fry. *Appetite* **51**, 576–591.

113. Clark AM, Duncan AS, Trevoy JE, *et al.* (2011) Healthy diet in Canadians of low socioeconomic status with coronary heart disease: not just a matter of knowledge, choice. *Heart Lung* **40**, 156–163.
114. Hinote BP, Cockerham WC, Abbott P (2009) Psychological distress and dietary patterns in eight post-Soviet republics. *Appetite* **53**, 24–33.
115. Pinho MGM, Mackenbach JD, Charreire H, *et al.* (2018) Exploring the relationship between perceived barriers to healthy eating and dietary behaviours in European adults. *Eur J Nutr* **57**, 1761–1770.
116. Sotos-Prieto M, Santos-Beneit G, Pocock S, *et al.* (2015) Parental and self-reported dietary and physical activity habits in pre-school children and their socio-economic determinants. *Public Health Nutr* **18**, 275–285.
117. Loose S, Peschel A & Grebitus C (2013) Quantifying effects of convenience and product packaging on consumer preferences and market share of seafood products: the case of oysters. *Food Qual Prefer* **28**, 492–504.
118. Tomić M, Matulić D & Jelić M (2016) What determines fresh fish consumption in Croatia? *Appetite* **106**, 13–22.
119. Forbes L, Graham J, Berglund C, *et al.* (2018) Dietary change during pregnancy, women's reasons for change. *Nutrients* **10**, 1032.
120. Burger J & Gochfeld M (2009) Perceptions of the risks and benefits of fish consumption: individual choices to reduce risk and increase health benefits. *Environ Res* **109**, 343–349.
121. Connelly NA, Lauber TB, Niederdeppe J, *et al.* (2014) How can more women of childbearing age be encouraged to follow fish consumption recommendations? *Environ Res* **135**, 88–94.
122. Lando AM, Fein SB, Choinière CJ, *et al.* (2012) Awareness of methylmercury in fish and fish consumption among pregnant and postpartum women and women of childbearing age in the United States. *Environ Res* **116**, 85–92.
123. Jacobs S, Sioen I, Marques A, *et al.* (2018) Consumer response to health and environmental sustainability information regarding seafood consumption. *Environ Res* **161**, 492–504.
124. Perez-Cueto F, Pieniak Z & Verbeke W (2011) Attitudinal determinants of fish consumption in Spain and Poland. *Nutr Hosp* **26**, 1412–1419.
125. Pieniak Z, Verbeke W & Scholderer J (2010) Health-related beliefs and consumer knowledge as determinants of fish consumption. *J Hum Nutr Diet* **23**, 480–488.
126. Skuland SE (2015) Healthy eating and barriers related to social class. The case of vegetable and fish consumption in Norway. *Appetite* **92**, 217–226.
127. Jovanović GK, Kresić G, Zezelj SP, *et al.* (2011) Cancer and cardiovascular diseases nutrition knowledge and dietary intake of medical students. *Coll Antropol* **35**, 765–774.
128. Stimming M, Mesch CM, Kersting M, *et al.* (2015) Fish and rapeseed oil consumption in infants and mothers: dietary habits and determinants in a nationwide sample in Germany. *Eur J Nutr* **54**, 1069–1080.
129. Altintzoglou T, Vanhonacker F, Verbeke W, *et al.* (2011) Association of health involvement and attitudes towards eating fish on farmed and wild fish consumption in Belgium, Norway and Spain. *Aquac Int* **19**, 475–488.
130. Tiainen AM, Männistö S, Lahti M, *et al.* (2013) Personality, dietary intake – findings in the Helsinki birth cohort study. *PLOS ONE* **8**, e68284.
131. Gacek M (2014) Individual differences as predictors of dietary patterns among menopausal women with arterial hypertension. *Prz Menopauzalny* **13**, 101–108.
132. Sapranaviciute-Zabazlajeva L, Luksiene D, Virviciute D, *et al.* (2017) Link between healthy lifestyle, psychological well-being in Lithuanian adults aged 45–72: a cross-sectional study. *BMJ Open* **7**, e014240.
133. Dijkstra SC, Neter JE, van Stralen MM, *et al.* (2015) The role of perceived barriers in explaining socio-economic status differences in adherence to the fruit, vegetable and fish guidelines in older adults: a mediation study. *Public Health Nutr* **18**, 797–808.
134. Bord Bia (2017) Irish seafood overview. http://www.bordbiavantage.ie/market-information/sector-overviews/irish-seafood-overview/2017 (accessed October 2019).
135. Bord Bia (2018) Fish & seafood: an analysis of the Irish fish and seafood sector. https://www.bordbia.ie/industry/sector-profiles/fish-seafood/2018 (accessed October 2019).
136. York E (2019) Average income tends to rise with age. https://taxfoundation.org/average-income-age/ (accessed November 2019).
137. Irish Nutrition and Dietetic Institute (2016) What's the catch with Omega-3s? (accessed October 2020).
138. National Institutes of Health (NIH) (2019) Omega-3 fatty acids – fact sheet for health professionals. https://ods.od.nih.gov/factsheets/Omega3FattyAcids-HealthProfessional/ (accessed July 2020).
139. Burr ML, Trembeth J, Jones KB, *et al.* (2007) The effects of dietary advice, vouchers on the intake of fruit, fruit juice by pregnant women in a deprived area: a controlled trial. *Public Health Nutr* **10**, 559–565.
140. Oken E, Guthrie LB, Bloomingdale A, *et al.* (2013) A pilot randomized controlled trial to promote healthful fish consumption during pregnancy: the Food for Thought Study. *Nutr J* **12**, 33.
141. Gittelsohn J, Trude ACB, Kim H (2017) Pricing strategies to encourage availability, purchase, and consumption of healthy foods and beverages: a systematic review. *Prev Chronic Dis* **14**, E107.
142. Afshin A, Peñalvo JL, Del Gobbo L, *et al.* (2017) The prospective impact of food pricing on improving dietary consumption: a systematic review and meta-analysis. *PLOS ONE* **12**, e0172277.
143. Wall J, Mhurchu CN, Blakely T, *et al.* (2006) Effectiveness of monetary incentives in modifying dietary behavior: a review of randomized, controlled trials. *Nutr Rev* **64**, 518–531.
144. Mertens E, Kuijsten A, Dofková M, *et al.* (2019) Geographic and socioeconomic diversity of food and nutrient intakes: a comparison of four European countries. *Eur J Nutr* **58**, 1475–1493.
145. Hiza HA, Casavale KO, Guenther PM, *et al.* (2013) Diet quality of Americans differs by age, sex, race/ethnicity, income, and education level. *J Acad Nutr Diet* **113**, 297–306.
146. Mohan Dey M, Rab MA, Paraguas FJ, *et al.* (2007) Fish consumption and food security: a disaggregated analysis by types of fish, classes of consumers in selected Asian countries. *J Aquac Econ Manag* **9**, 89–111.
147. Ha E & Caine-Bish N (2009) Effect of nutrition intervention using a general nutrition course for promoting fruit and vegetable consumption among college students. *J Nutr Educ Behav* **41**, 103–109.
148. Carpenter R, Finley C & Barlow C (2004) Pilot test of a behavioral skill building intervention to improve overall diet quality. *J Nutr Educ Behav* **36**, 20–26.
149. Girard A & Olude O (2012) Nutrition education and counselling provided during pregnancy: effects on maternal, neonatal and child health outcomes. *Paediatr Perinat Epidemiol* **26**, 191–204.
150. Geaney F, Kelly C, Greiner B, *et al.* (2013) The effectiveness of workplace dietary modification interventions: a systematic review. *Prev Med* **57**, 438–447.

British Journal of Nutrition

151. De Bourdeaudhuij I, Van Cauwenberghe E, Spittaels H, *et al.* (2011) School-based interventions promoting both physical activity and healthy eating in Europe: a systematic review within the HOPE project. *Obes Rev* **12**, 205–216.
152. Manios Y, Moschonis G, Katsaroli I, *et al.* (2007) Changes in diet quality score, macro- and micronutrients intake following a nutrition education intervention in postmenopausal women. *J Hum Nutr Diet* **20**, 126–131.
153. Henry C, Woo J, Lightowler H, *et al.* (2003) Use of natural food flavours to increase food and nutrient intakes in hospitalized elderly in Hong Kong. *Int J Food Sci Nutr* **54**, 321–327.
154. Zhu H & An R (2013) Impact of home-delivered meal programs on diet and nutrition among older adults: a review. *Nutr Health* **22**, 89–103.
155. Roy M & Payette H (2006) Meals-on-wheels improves energy and nutrient intake in a frail free-living elderly population. *J Nutr Health Aging* **10**, 554–560.
156. Young K, Binns M & Greenwood C (2001) Meal delivery practices, do not meet needs of Alzheimer patients with increased cognitive and behavioral difficulties in a long-term care facility. *J Gerontol A Biol Sci Med Sci* **56**, M656–M661.
157. Diez-Roux A, Nieto F, Caulfield L, *et al.* (1999) Neighbourhood differences in diet: the Atherosclerosis Risk in Communities (ARIC) Study. *J Epidemiol Community Health* **53**, 55–63.
158. Bakre AT, Song Y, Clifford A, *et al.* (2018) Determinants of fish consumption in older people: a community-based cohort study. *J Aging Res Clin Pract* **7**, 163–175.
159. Sahyoun NR, Pratt CA & Anderson A (2004) Evaluation of nutrition education interventions for older adults: a proposed framework. *J Am Diet Assoc* **104**, 58–69.
160. McManus A, White J, Newton W, *et al.* (2011) Community intervention to increase seafood consumption (CIISC). Centre of Excellence for Science Seafood, Health (CESSH), Curtin Health Innovation Research Institute, Curtin University. Contract No.: Report # 16092011.

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