

The Effect of Seafood Consumption on the Memory of Post-Secondary Students in B.C.

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Abstract

Background and Purpose: Seafood makes up a significant portion of the diets of people around the world. Especially fatty fish such as salmon and herring, seafood items contain numerous nutritional benefits including omega-3 fatty acids which studies have shown aid in cognition and memory. However, due to natural and anthropogenic sources of pollution, contaminants such as mercury which studies suggest decreases cognitive functioning if consumed in excess bioaccumulate in marine life including various fish and shellfish species. The purpose of this study was to categorize participants into either the “fish” group (more fish than shellfish consumed) or the “same” group (either more shellfish than fish consumed or equal amounts of fish and shellfish consumed) via a seafood frequency questionnaire, and to administer a memory test to the participants to determine whether there is a significant difference in mean memory test scores between the groups.

Methods: 31 participants were randomly selected at BCIT to participate in the study. Participation was voluntary and participants were given written and oral instructions on how to complete both the seafood frequency questionnaire and memory test. Memory test scores were based on the length of the longest digit sequence that the participant was able to recite upon hearing the examiner list the sequence. The highest possible score was a 10, while the lowest possible score was a 1.

Results: The mean memory test scores of the groups, “fish” (more fish than shellfish consumed) and “same” (either more shellfish than fish consumed or equal amounts of fish and shellfish consumed), were 5.83 and 5.92, respectively. The median memory test scores of the groups, “fish” and “same”, were both equal to 6. The standard deviations of the groups, “fish” and “same”, were 1.2004901 and 0.9540736, respectively. The ranges of the groups, “fish” and “same”, were 4 (minimum) to 8 (maximum) and 5 (minimum) to 8 (maximum). From the non-parametric Wilcoxon Rank sum test, the P-value was found to be >0.05 at $\alpha = 0.05$.

Conclusion: The results of this study suggest that diets relatively high in fish are neither positively nor negatively correlated with memory. However, the limitations

of this study in combination with the various studies that contradict this study's findings illustrate the need for further research.

Keywords: memory, seafood, shellfish, fish, PCBs, mercury, brain, neurodevelopment, DHA, EPA and omega-3 fatty acids

Introduction

Seafood is consumed regularly by people from all over the world. From sushi to seafood chowders, the many marine species that exist make up a significant part of people's diets, with seafood being the primary source of animal protein for over one billion people worldwide (1). In addition to being an important protein source, seafood offers several key benefits to human health. For example, the consumption of omega-3 fatty acids found in oily fish such as salmon and herring correlates to a reduction in mortality from cardiovascular disease (2).

Additionally, the consumption of fish rich in docosahexaenoic acid (DHA), a type of omega-3 fatty acid, during pregnancy assists in brain development during gestation as well as early infancy (2). Conversely, some key risks associated with seafood consumption have also been studied. Exposure to polychlorinated phenyls (PCBs), which are toxic, manmade compound that collect in fish via contaminated waters (e.g. the Great Lakes), is associated with impaired memory and learning in both childhood and adulthood (3). Benefits and risks associated with seafood consumption such as the ones listed above have influenced documents such as Canada's Food Guide, which not only recommends a minimum of 150 grams of cooked fish be consumed weekly for adults, but also a limit to the consumption of certain seafood items high in dangerous chemicals for specified risk groups (e.g. limit fish high in mercury for pregnant women) (4). Because of the prevalence of seafood in our diets, it becomes increasingly important to further understand the benefits and risks associated with seafood consumption. This literature review seeks to investigate a specific area regarding seafood consumption: namely, the effect that seafood consumption has on human memory. Studies have been conducted on the effect of seafood consumption on the memory of young children, young adults, and older adults. This review seeks to synthesize the relevant journal articles, studies, and government documents in place. Also, it will identify the key findings regarding the benefits and risks that seafood consumption poses on human memory, as well as the knowledge gaps that stem from them.

Evidence Review

Omega-3 Fatty Acids:

Omega-3 fatty acids are unsaturated dietary fatty acids associated with healthy aging and improvements to physical and mental health (5). Although humans are capable of producing some omega-3 fatty acids, it is usually not enough from a developmental standpoint, meaning humans must acquire them from external sources such as marine sources (5). Fatty fish such as salmon, anchovies, and

herring are rich in omega-3 fatty acids, namely two specific omega-3 fatty acids called eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) which, together, confer many benefits to human health (2). DHA, for example, is a component of neural membranes and plays a significant role in nervous system functioning (5). Some of the benefits of EPA and DHA include improved cardiovascular function, improved fetal eye and brain development during pregnancy, as well as a decreased risk in developing certain diseases such as cardiovascular diseases and Alzheimer's disease (5). Additionally, some studies have shown that in those with mild Alzheimer's disease, a progressive, incurable disease characterized by impairments to cognition and bodily function, a combination of EPA and DHA somewhat improved cognition and helped control unintended weight loss (5). As suggested by a study by Xiao et al. (2006), DHA deficiency is actually linked to impaired memory as well as spatial learning (6). However, this study was performed using adult rat subjects so its generalization to humans is questionable.

Contaminants Found in Seafood:

Mercury is an environmental contaminant that is prevalent in many retail fish species. Although mercury can naturally occur in the environment via rocks and soil, human activities such as waste incineration, mining, and the burning of coal also release large quantities into the environment, including water bodies where fish reside (7). As fish swim in contaminated waters, their muscles absorb the mercury present in the water (7). Additionally, as fish on the lower end of the aquatic food chain are consumed by more predatory fish, mercury becomes more concentrated in fish towards the top of the food chain. As a result, predatory fish that prey on many smaller fish such as tuna, shark, and swordfish accumulate the highest levels of mercury and are, therefore, the riskiest to consume (7). Health Canada, for example, advises that Canadians limit their consumption of such predatory fish due to mercury, with recommendation being 150g per week for the general population, 150g per month for pregnant and breastfeeding women, 125g per month for children aged 5 to 11 years old, and 75g (i.e. 1 Canada's Food Guide's serving) for children aged 1 to 4 years old (8). Although some mercury in the blood is necessary for normal cognitive function, having too much mercury, as well as too little mercury, may hinder specific areas of cognitive functioning. For example, in a study of 384 men and women conducted by Masley et al. (2012), subjects with elevated (and lower) mercury concentrations in their blood performed poorer than subjects with normal blood mercury in a complex information processing (CIP) test, which measures reaction times and an "individual's ability to shift from one instruction set to another quickly and accurately" (9).

Polychlorinated biphenyls (PCBs) are synthetic chemicals that were used in manufacturing from the late 1920s to the late 1970s (10). Because of their harm to the environment and human health, PCBs were eventually made illegal in Canada by the federal government by the 1980s, the exception being that owners are allowed to use PCB-containing equipment "until the end of its service life" (10). However, despite the regulatory controls in place, PCBs are still

released into the environment via accidental fires and spills, negatively affecting aquatic ecosystems, the aquatic organisms within them, as well as humans who eat them. For instance, PCB exposure during pregnancy is associated with impaired intellectual functioning of young children (3). Additionally, in a study with participants aged 49 to 86 conducted by Schantz et al. (2001), results showed an association between increased PCB exposure in adulthood to impaired cognitive functioning in the areas of memory and learning (3). Specifically, “fish eaters”, defined as participants who ate more than 24 pounds of PCB-contaminated Lake Michigan fish per year, had higher PCB exposure and delayed verbal recall in comparison to “non-fish eaters”, who are defined as participants who ate less than 6 pounds of PCB-contaminated Lake Michigan fish per year (3). According to the same study, visual-spatial function and executive function (e.g. the ability to sustain and switch focus) were not associated with PCB exposure (3).

Because of the prevalence of contaminants such as mercury and PCBs in seafood that can negatively affect human health, it is important to eat fish and shellfish high in omega-3 fatty acids and low in contaminants such as mercury (8). Fish and shellfish that fall in this category include anchovies, herring, salmon, smelt, and shrimp (8). In fact, the results of a study conducted by Gerber et al. (2012) showed unsustainable seafood (categorized as “Red” in the Monterey Bay Aquarium (MBA) Seafood Watch rankings) as generally having significantly more mercury but not beneficial omega-3 fatty acids than more sustainable seafood (categorized as “Yellow” and “Green” in the MBA Seafood Watch rankings) (11). By extension, the larger, longer-living, predatory marine species such as most tuna species, which are often the most overfished and unsustainable, are often riskier to consume from a human health perspective due to their high mercury content (11). This is in line with standards such as the ones that exist in Canada that limit the allowable contaminant concentrations in retail foods (e.g. a maximum of 0.5mg of mercury is allowed per kg of “the edible portion of all retail fish” to minimize the human health risks associated with them (12).

Potential Memory Impact of Seafood Consumption:

Insufficient quantities of essential nutrients during the initial 2 years of life, as well as the final trimester during pregnancy can negatively impact the neurodevelopment of children (13). One of these nutrients is DHA, which is passed from the mother to her child via the placenta (during pregnancy) and breastfeeding. Women that consume more fish or fish oils have higher DHA levels to confer to their children during the brain growth spurt, which occurs late in a pregnancy (i.e. final trimester) as well as early childhood (13).

To examine the effect of pre-natal DHA conferral on the neurodevelopment of young children, a study was conducted between 1997 and 2001 in Spain by Mendez et al. (2008) showing an association between maternal intake of fish and benefits in the neurodevelopment of their children (13). Specifically, four year old children whose mothers ate fish more than 2 to 3 times a week performed better than children of mothers that ate fish less than once a week on the McCarthy Scales of Children’s Abilities (MCSA) tests, which examine neurodevelopment via five levels: perceptive-performance, memory,

verbal, quantitative, and motor (13). This finding was for children who were breast-fed for less than 6 months. Another study conducted in Arctic Quebec with school-aged Inuit children (median age 11.3 years old) by Boucher et al. (2011) suggests that there exist long-term benefits of prenatal omega-3 fatty acid intake on memory as well (14).

Conversely, maternal intake of other seafood such as octopi and squid, which have lower DHA content than fish, was associated with a decrease in score on several of the MCSA test levels conducted in the study by Mendez et al. (2008) (13). Although the reason for this finding is unknown, the study mentions the possibility of high mercury content in predatory species like octopi and squid as being a contributing factor, as some (though, not all) studies associate increased mercury intake with cognitive deficiency (13). This would agree with the study conducted by Masley et al. (2012) stating that “rising Hg levels ultimately overwhelm the moderating effect [on improved cognitive function] of N3FA (omega-3 fatty acids) intake” (9).

Some studies have also found a positive correlation between fish consumption and memory in adults. For example, one study conducted by Raji et al. (2014) among elderly adults (aged 65 and up) found an association between consuming broiled or baked fish at least once a week and increased grey matter, specifically within “areas of the brain responsible for memory and cognition” (15). Interestingly, the increase in grey matter was independent from the effects of omega-3 fatty acids like DHA and EPA, with the study suggesting that it may be lifestyle factors, “and not necessarily...biological factors (e.g. omega-3 fatty acids)” that affect brain structure and brain function (15). On the other hand, studies such as one conducted by Stonehouse et al. (2013) suggest that DHA supplements improve memory and response times in otherwise healthy, young adults with low consumption of DHA-rich foods (16). Specifically, DHA supplementation improved “episodic memory” in women and improved response times in men (16).

Methods

Purpose:

Seafood is eaten universally and remains an important food source for people around the world, with seafood being the primary source of protein for more than one billion people (1). Due to this and the sheer variety of seafood items and dishes that exist, it is important to learn more about the effect of seafood on health. The aspect of health that this study focused on was memory and specifically aimed at examining the effect that fish and shellfish consumption has on the memory of post-secondary students in B.C., as members of this target population tend to regularly and rigorously use memory during the course of their studies.

There have been studies on the risks and benefits of eating fish and shellfish, which include the neurological benefits of DHA (e.g. during fetal development) and the neurological detriments of mercury. However, there are not any studies that directly focus on the respective effects that fish and shellfish

species have on memory. Therefore, the purpose of this study was to explore this by determining whether or not there were significant differences in the mean memory test scores between post-secondary students in B.C. who eat more shellfish than fish, post-secondary students in B.C. who eat more fish than shellfish, and post-secondary students in B.C. who eat equal amounts of both. Ultimately, the study aimed to reduce the knowledge gaps present in this topic area and provide additional evidence on the impacts that different seafood items have on memory (in this case, on post-secondary adults). Before the study began, the following null (H_0) and alternate hypotheses (H_a) were established:

H_0^1 : There is no difference in the mean memory test scores between post-secondary students in B.C. who eat more shellfish than fish and post-secondary students in B.C. who eat more fish than shellfish.

H_0^2 : There is no difference in the mean memory test scores between post-secondary students in B.C. who eat more shellfish than fish and post-secondary students in B.C. who eat equal amounts of fish and shellfish.

H_0^3 : There is no difference in the mean memory test scores between post-secondary students in B.C. who eat more fish than shellfish and post-secondary students in B.C. who eat equal amounts of fish and shellfish.

H_a^1 : There is a difference in the mean memory test scores between post-secondary students in B.C. who eat more shellfish than fish and post-secondary students in B.C. who eat more fish than shellfish.

H_a^2 : There is a difference in the mean memory test scores between post-secondary students in B.C. who eat more shellfish than fish and post-secondary students in B.C. who eat equal amounts of fish and shellfish.

H_a^3 : There is a difference in the mean memory test scores between post-secondary students in B.C. who eat more fish than shellfish and post-secondary students in B.C. who eat equal amounts of fish and shellfish.

However, by the end of the study, only a small sample size was achieved for each group ($n=18$ for the group that predominantly eats fish; $n=10$ for the group that eats equal amounts of fish and shellfish; $n=3$ for the group that predominantly eats shellfish). The data for both the group that eats equal amounts of fish and shellfish and the group that predominantly eats shellfish are especially limited. Therefore, the participants who reportedly eat equal amounts of fish and shellfish ($n=10$) and the participants who reportedly eat more shellfish than fish ($n=3$) were combined into one group: the group that eats either equal amounts of fish and shellfish *or* more shellfish than fish ($n=13$). The null and alternate hypotheses were re-established as the following:

H_0 : There is no difference in the mean memory test scores between post-secondary students in B.C. who eat more fish than shellfish (group 1) and post-secondary students in B.C. who eat either equal amounts of fish and shellfish *or* more shellfish than fish (group 2).

H_a : There is a difference in the mean memory test scores between post-secondary students in B.C. who eat more fish than shellfish (group 1) and post-secondary students in B.C. who eat either equal amounts of fish and shellfish *or* more shellfish than fish (group 2).

Due to the limited data attained, the purpose of the study was reduced to determining whether the memory test scores of post-secondary students in B.C. who eat more fish than shellfish were significantly different from the memory test scores of post-secondary students in B.C. who *do not* eat more fish than shellfish.

Methods and Materials

Prospective participants were randomly selected from the pool of BCIT students physically present at BCIT and were approached by the same administrator. Initially, prospective participants were randomly selected via systematic sampling, with every 5th person exiting the library at BCIT's (Burnaby campus) SE14 building being approached (17). However, this method garnered few responses and a new method of randomly approaching students throughout BCIT's SW1 building was devised. This new method generated a greater amount of participation, though at the expense of internal validity. For instance, approaching students throughout BCIT's SW1 building meant that participants were not tested at a common location, as different hallways, rooms, and other areas within the building may have had varying levels of noise which could have impacted the responses and memory test scores of participants.

All participants were briefed on the study in the same manner via the script in Appendix A and the cover letter in Appendix B, including the reason for the study, the purpose of the study, what the study tested and consisted of, as well as the study's regard for volunteerism, confidentiality, and anonymity (17). Prospective participants were free to decline, as well as withdraw during the course of the study if they wished (17). Participants were asked to sign a consent form stating that they agreed to participate in the study and that they were old enough (19 years or older) to consent (see Appendix C). They were given instructions on how to complete both the questionnaire and the memory test (Appendix D) and also were asked to indicate their program of study as well as the amount of sleep they received the night before, as both potentially could have influenced the maximum number of digits they memorized in the memory test. Additionally, they were offered a 12.5g packet of Maynards' Fuzzy Peaches candy for participating, as "providing incentives" is known to increase the response rate of surveys by anywhere between 8 to 30% (17). Although the goal was to approach prospective participants until there were at least 30 participants available in each of the initial three groups, time constraints as well as an unprecedented lack of participants who eat more shellfish than fish ultimately lead to the small sample sizes used and the merging of two of the initial three groups (i.e. the group that eats equal amounts of fish and shellfish; and the group that predominantly eats shellfish) into one group (17).

Participants were each given two parts to complete: one seafood frequency questionnaire and one memory test. They were also given a pencil to complete the seafood frequency questionnaire if they did not have one.

The purpose of the seafood frequency questionnaire (Appendix D, part 1) was to determine which of the two groups each participant fell under ("fish" and "same" (Appendix E, figure 1)). The questionnaire inquired about the frequency

and quantity of consumption of various seafood item categories, which were classified as either “fish” or “shellfish” species. The following categories were the common “fish” species mentioned on the questionnaire: anchovy, bass, carp, catfish, cod, eel, flounder, halibut, herring, mackerel, salmon, sardine, shark, smelt, snapper, sturgeon, tilapia, trout, and tuna (18). The following categories were the common “shellfish” species mentioned: abalone, clam, cockle, conch, limpets, mussels, octopus, oysters, periwinkle, scallops, land and sea snails, squid, whelks, lobster, and shrimp (18). The amount of “fish” eaten per week by each participant was calculated by multiplying the “frequency” of consumption with the “quantity” for each of the “fish” species categories above and adding them all together. For example, if a participant indicated that he/she eats salmon “4-6 times per week” with a usual serving size of “less than ½ of a Canada Food Guide serving” it would have been noted that he/she eats between 2 and 3 servings of salmon per week (4×0.5 servings to 6×0.5 servings = 2 to 3 servings). If the same participant eats, for example, 4 to 6 servings of tuna per week and no other “fish” species, then it would have been noted that he/she eats 6 to 9 servings of “fish” species per week ($[2+4]$ servings (minimum) to $[3+6]$ servings (maximum) = 6 to 9 servings). The amount of “shellfish” species eaten per week was calculated in the same way, except that “shellfish” species categories were concerned instead of “fish” species categories. The amount of “fish” species eaten was compared with the amount of “shellfish” species eaten for each participant. Afterwards, participants were put into their respective groups accordingly. The “fish” group in Appendix E, figure 1 represents participants who eat more “fish” species than “shellfish” species per week. The “same” group represents participants who either eat equal amounts of “fish” species and “shellfish” species per week or more “shellfish” species than “fish” species per week. It took approximately 5-7 minutes for participants to complete the questionnaire.

After completing the questionnaire, participants were given a memory test. At the start of the memory test, the administrator listed a sequence of two digits at a speed of one digit per second, followed by saying the word “repeat”. Upon hearing the administrator say “repeat”, participants were to recite to the administrator the exact sequence of digits that preceded the “repeat” in the correct order (forward, not backwards). After reciting the first series of digits, the administrator began listing a second sequence of digits one digit longer than the first (i.e. three digits), followed by the word “repeat”. Then, participants were to recite to the administrator the exact sequence of digits that preceded the second “repeat” (i.e. the second sequence of digits) in the correct order. This back-and-forth recital of digit sequences continued, with the length of digit sequences to be recited increasing by 1 digit after each consecutive sequence (i.e. 2-digit sequence, then 3-digit sequence, then 4-digit sequence, and so on). If a sequence of a particular length was incorrectly recited, the administrator listed another sequence of digits of the same length for the participants to recite. The memory test ended if participants incorrectly recited two digit sequences of a particular length (e.g. two 8-digit sequences were incorrectly recited) or if participants successfully reached and recited the final sequence (i.e. a sequence

of ten digits). During the memory test, the administrator followed along on a copy of "Appendix D, Part 2" and gave each participant a score based on the length of the longest digit sequence recited. For example, if a 10-digit sequence was correctly recited, the participant would have been given a score of 10, the highest possible score. If the participant were to reach the 10-digit sequence stage but incorrectly recite both 10-digit sequences, the participant would have been given a score of 9. If the participant were to incorrectly recite both 2-digit sequences, the participant would have been given a score of 1, the lowest possible score. It took approximately 1-2 minutes for participants to complete the memory test. On average, 6-9 minutes was the time it took for participants to complete both the questionnaire and the memory test. Additionally, each participant was thanked for their participation by the administrator and given a 12.5g packet of Maynards' Fuzzy Peaches candy.

Analysis of the data collected was conducted using statistical software known as SAS on a personal computer (Prelude-PC).

Description of Standard Methods:

The script and questionnaire were custom-made for the study. Conversely, the memory test was an adaptation of the "digit span" short-term memory test, which is "among the oldest and most widely used neuropsychological tests of short-term verbal memory" (19). Like a typical measure of digit span, the memory test used in the study entailed the recital of digit sequences, starting with a 2-digit sequence which increased in length as the memory test progressed (19). Additionally, the memory test ended if the participant incorrectly recited two digit sequences of a particular length (e.g. two 8-digit sequences are incorrectly recited) or if participants successfully reached and recited the final sequence (19). However, in the interest of time, the memory test used in this study differed from a typical measure of digit span in several ways. Firstly, it did not measure backward span, meaning participants were only required to recite the digit sequence in the exact order it was presented and not backwards (e.g. if the administrator listed the sequence "0, 9, 6, 5", the participant was to recite "0, 9, 6, 5", not "5, 6, 9, 0") (19). Secondly, if a participant correctly recited the first digit sequence of a particular length (e.g. "3, 5, 2, 1, 6" of the *5-digit sequences* level in Appendix D, Part 2), then the second digit sequence of the length in question (e.g. "7, 0, 9, 2, 4" of the *5-digit sequences* level in Appendix D, Part 2) would *not* have been given to the participant, who instead would have been given the first digit sequence of the next length (e.g. "9, 4, 3, 8, 6, 0" of the *6-digit sequences* level in Appendix D, Part 2). Lastly, instead of a maximal digit sequence length of 9 digits, the memory test of this study employed a maximal digit sequence length of 10 digits.

Inclusion and Exclusion Criteria:

Because the focus of the study was on how seafood consumption affects the memory of post-secondary students in B.C., there were key inclusionary and exclusionary criteria in place.

Participants were randomly selected from the defined population, which is the population of post-secondary students in B.C. Instructors or other staff at post-secondary institutions were not included. Due to availability and convenience, only BCIT students present in the Burnaby campus at the time of the survey were approached in person to participate in the study. Non-post-secondary students and students who did not physically attend class at BCIT's Burnaby campus (e.g. distance education, on co-op) were excluded from participating in the study. People who fell under the aforementioned criteria were given an equal chance of participating in the study regardless of sex and race. However, due to informed consent laws in B.C., only participants aged 19 or over were allowed to consent and participate in the study (20).

Ethical Considerations:

As this was a human-based study with human participants, ethics was considered, specifically regarding beneficence and autonomy (17).

Regarding beneficence, aside from taking up approximately 6-9 minutes of the participants' time, participation in the study did not pose significant risk or discomfort to the lives of participants. Questions posed in the survey did not inquire about sensitive topics such as income, drug use, alcohol, and sexual activity and were unlikely to be perceived as personal or intrusive (17). Additionally, participating in the study potentially could have "[contributed] to scientific knowledge [which] is considered adequate benefit" (17).

Regarding autonomy, prospective participants were briefed on the details of the study, including its purpose, procedures, risks, and benefits. Participation in the study was also on a volunteer basis, with the guarantee that the results and identity of the participants be kept confidential (17). Additionally, the questions and their choices posed in the surveys, as well as any instructions explained orally to the participants, were made very clear and neutral to maximize understanding and minimize biases and leading of the participants.

Results

Description of Data:

The types of data collected in the study were ordinal data and numerical data (21).

Questions regarding the frequency and quantity of each seafood item they eat were on the survey and had options regarding consumption of the seafood item in increasing order. For example, for each seafood item, participants ticked off one of the following mutually exclusive categories regarding how frequently they eat it: "unsure", "never", "less than once a week", "1-3 times per week", "4-6 times per week", and "7 times (e.g. once a day) or more per week". Regarding quantity (i.e. the usual serving size for each seafood item), the options were "less than ½ of a Canada Food Guide", "one Canada Food Guide Serving", and "more than 1.5 times a Canada Food Guide Serving". Because there was an order to the options, data obtained from these questions was ordinal data (21). The

purpose of this data was to assign each participant into one of the two groups: “fish” or “same” (Appendix E, figure 1).

The memory test following the end of the survey involved the participants reciting digit sequences given by the administrator, who gave each participant a score based on the length of the longest digit sequence they were able to recite. For example, a participant scored a 9 if they correctly recited a 9-digit sequence but failed to correctly recite both 10-digit sequences. The possible memory test scores were between 1 and 10, with a 1 assigned to participants who failed to correctly recite both 2-digit sequences. As a score could only be a whole number, the data obtained from this test was discrete, numerical data (21).

Descriptive Statistics:

As illustrated by the data run on SAS, the sample size of the study was 31 disregarding the 2 participants who submitted incomprehensible and incorrectly-filled questionnaires (30 participants in each group would have been ideal, but was not possible due to time constraints and an unprecedented lack of participants who eat more shellfish than fish). 18 participants fell into the “fish” group (more fish than shellfish consumed) while 13 participants fell into the “same” group (either more shellfish than fish consumed *or* equal amounts of fish and shellfish consumed). From the results of the memory test the participants in the sample took, a mean, standard deviation, range (difference between the maximum and minimum values), and median were obtained for each group. The mean and median are “measures of central tendency” and the standard deviation and range are “measures of spread” (21). As shown in Appendix E, at least one of the P-values produced from the normality tests under “T Tests” on SAS was > 0.05 (e.g. $P = 0.1174$ for the Shapiro-Wilk Test for “shl_vs_fsh = fish”), indicating that the data was not normally distributed (22).

Inferential Statistics

A two-tail t-test was performed to determine whether or not there was a significant difference in the memory of the 2 groups. Studies are somewhat mixed in determining the effect fish consumption has on memory (especially across different fish species due to varying levels of omega-3 fatty acids, mercury, etc.) so a two-tail t-test was selected over a one-tail t-test (22). According to the normality tests under “T Tests” on SAS, the data was not normally distributed (at least one of the P-values produced from the normality tests was > 0.05), indicating that the results of the (non-parametric) Wilcoxon Rank sum test should be consulted (22). As well, the Wilcoxon Rank sum test should be used if the sample size is under 30 for one or more groups, which was the case in this study (22).

Through the analysis on SAS, the P-value can be determined which, depending on the “acceptable alpha” (usually 0.05), determines whether or not to reject the null hypothesis and conclude that there is a significant difference in memory between post-secondary students in B.C. who eat more fish than shellfish (group 1) and post-secondary students in B.C. who either eat equal amounts of fish and shellfish or more shellfish than fish (group 2) (21). Ultimately, the results of the

statistical inference can be extrapolated to the defined population of the study, which is the population of post-secondary students in B.C. (21).

Interpretation of Data:

As illustrated by Appendix E, figure 1, the mean scores on the memory test were 5.83 and 5.92 for group 1 and group 2, respectively. The means were not significantly different from each other according to the analysis of the data on SAS.

The results of the non-parametric Wilcoxon Rank sum test (Appendix E, figure 5) showed that the P-value for the one-tail and two-tail t-tests were 0.4754 and 0.9508, respectively (the P-values under “normal approximation” of the Wilcoxon Rank sum test were not looked at as the observations in each group were not normally distributed). At $\alpha = 0.05$, the P-values from the Wilcoxon Rank sum test, which were > 0.05 , indicated that there was not a significant difference between the mean memory test scores of group 1 (participants who eat more fish than shellfish) and group 2 (participants who either eat equal amounts of fish and shellfish or more shellfish than fish). Therefore, the null hypothesis was not rejected and it was concluded that there was not a significant difference in mean memory test scores between the two groups.

Discussion

Regardless of how they are prepared and the dishes they are incorporated into, fish and shellfish species make up a significant part of peoples' diets, with seafood being the primary source of animal protein for over one billion people worldwide (1). Consequently, there has been extensive research into both the benefits and risks to human health, such as cognitive function and memory, associated with seafood consumption. According to previous studies, these benefits and risks to memory are attributed to both the inherent characteristics (e.g. DHA content) of the seafood items themselves and the environmental contaminants (e.g. PCBs, mercury) that bioaccumulate in marine species. Although, depending on the study, the relationship between seafood consumption and memory can vary significantly.

Between the group of 18 participants who eat more fish than shellfish (group 1) and the group of 13 participants who either eat equal amounts of fish and shellfish or more shellfish than fish (group 2), there was no significant difference in the mean memory test scores which were 5.83 and 5.92 ($P = 0.9508$) for group 1 and group 2, respectively. The results of this study imply that a diet high in fish as opposed to other seafood items (i.e. shellfish items) has neither a beneficial nor detrimental effect on human memory (the accuracy and meaningfulness of this study's findings are diminished due to limitations outlined in the “Limitations” section below). Results from a 5-year “double-masked randomized clinical” study supported by the National Institutes of Health (NIH) looking at the effect on cognitive function of omega-3 fatty acids, beneficial dietary fatty acids such as EPA and DHA commonly found in fatty fish, indirectly support the findings of this study (5, 23). Among the 3,073 participants (mean

age = 72.7 years; 57.5% of participants were female) who were all at risk of developing age-related macular degeneration (AMD), there was no significant difference in the “yearly change in the composite cognitive function score (which is a function of 8 different cognitive tests including the “Wechsler Memory Scale” which assesses attention and memory) between those assigned to the group receiving the omega-3 fatty acid supplement (yearly change = -0.19 (99% CI, -0.25 to -0.13)) and those assigned to the group receiving the placebo (yearly change = -0.18 (99% CI, -0.24 to -0.12)) (23). The old age and declining health of the participants, the fact that “omega-3 fatty acids may take years or decades to exert an effect”, and the fact that “high dose omega-3 supplementation is not the same as eating high amounts of omega-3s in a healthy dietary pattern high in marine fish” may have contributed to the study’s unique results (24).

Contrary to both this study and the aforementioned 5-year NIH study, many studies have found correlations between fish consumption and cognitive function (e.g. memory). For example, an American cohort study found a positive correlation between maternal (DHA-rich) fish consumption during pregnancy and the visual recognition memory of infants (25). Another cohort study similarly found that the neurodevelopmental scores of children were positively correlated with maternal fish consumption (26). Furthermore, a study from the Women’s Health Study found that participants (mean age = 72 years; 100% of participants were female) who reported eating dark-meat finfish or tuna once or more a week had significantly superior verbal memory than participants who reported eating either of those fish species less than once a week (27). As well, a study conducted in Auckland, New Zealand with 176 adults aged 18 to 45 years old found near opposite results to the 5-year NIH study (16). Specifically, it found a positive correlation between DHA supplementation and episodic memory in women as well as between DHA supplementation and reaction time in men (16).

Although this study ultimately did not examine the relationship between shellfish consumption and memory, studies have found correlations between the two. One such study was conducted in Spain, which found that maternal intake of octopi and squid (shellfish species), which both have lower DHA content than fish, had a negative correlation with the McCarthy Scales of Children’s Abilities (MCSA) test scores, which examine child neurodevelopment via five levels including memory (13). On the contrary, the aforementioned study from the Women’s Health Study found no correlation between shellfish consumption and verbal memory, as well as between light-meat finfish consumption and verbal memory (27).

It is important to note that, although slightly mixed, the results of many studies are contrary to this study’s results and have found that seafood consumption is associated with certain benefits and risks to cognition and memory depending on the type and amount consumed. As a result of such findings, governments like the Canadian government are constantly creating and reshaping resources, guidelines and policies to not only communicate to Canadians the importance and the dangers of eating seafood (e.g. mercury accumulation via excess tuna intake), but also to regulate the import and export

of seafood products and ensuring that they meet standards such as labeling and maximum allowable contaminant concentration requirements.

Recommendations

The results from this study suggest that eating seafood does not impact human memory. However, as previously mentioned, the limitations of this study diminish the meaningfulness of the results. As well, although there are some studies that support this study's findings, there are many studies that contradict them and identify positive correlations between fish consumption and memory across different groups including young children and the elderly. Therefore, concrete recommendations cannot be made based on the results of this one study alone.

Instead, more research is needed on the specific seafood items consumed in Canada, especially regarding their short and long-term positive and negative effects on the different types of human memory. By determining the possible negative effects specific seafood items can have on memory and the biochemical reasoning behind the negative effects, governmental and health resources, guidelines, and policies can be created and reshaped as needed. As well, new guidelines can be created for a variety of groups (e.g. pregnant women, immunocompromised, etc) regarding the maximum amount of a specific seafood item (e.g. servings per week) they should eat to avoid adverse effects on memory associated with eating the seafood item in question. In this way, people can educate themselves on these guidelines and the rationale behind them in order to make healthy choices with regards to seafood consumption.

Limitations

Several limitations emerged during the course of the study.

Initially, group 2 was divided into 2 other groups: the group of participants who eat equal amounts of fish and shellfish (group 2a) and the group of participants who eat more shellfish than fish (group 2b). However, due to time constraints and an unprecedented lack of participants who eat more shellfish than fish, the sample sizes for the study's initial 3 groups were small (<30 in each group; only 3 for group 2b). As a result of the small sample sizes, the sampling distribution of the mean for each group was not normal, diminishing the meaningfulness of this study's results (21).

Due to the lack of responses garnered from the initial method of systematic sampling (i.e. approaching every 5th person exiting the library at BCIT's SE14 building), the methodology was changed to randomly approaching students throughout BCIT's SW1 building. This new method increased the number of participants but resulted in a lack of a common testing location, meaning participants completed the questionnaire and memory test in an uncontrolled location with varying levels of noise and potential distractors. Also, many health programs are housed in SW1 and may have contributed to a biased sample.

Additionally, there may have been recall bias with regards to the questionnaire. For instance, people who eat more seafood may recall more accurately the frequency at which they eat specific seafood items (and their portions) compared to people who eat little to no seafood. It is also possible that some participants checked off “unsure” for a specific seafood item when they actually do in fact eat that seafood item (e.g. they did not know the seafood item’s name at the time of the questionnaire). As well, because the questionnaire inquired about the participant’s general consumption of the different seafood items, when the participants started eating different types of seafood (e.g. during childhood vs. during adolescence) as well as the participants’ mothers’ seafood consumption during pregnancy cannot be accurately described based on the structure of the questionnaire used.

With regards to the memory test, the test utilized was only an adaptation of the digit span test, meaning other types of memory including implicit memory, semantic memory, and episodic memory were not assessed (28). Additionally, factors including education, amount of sleep, frequency of alcohol consumption, recreational drug use, and smoking status may have affected memory test scores and were not assessed.

Future Research

1. Compare the accuracy of different methods (e.g. different phrasing/organization of questionnaires) of determining the participants’ true consumption of different seafood items.
2. Determine any correlations between various seafood items and the different types of memory (e.g. recall, verbal, procedural) across different age groups (e.g. children, adults, elderly).
3. Determine whether there is a difference in memory test scores between people who consume a diet high in DHA-rich seafood and people who primarily get DHA from supplements rather than through foods like fish.
4. For a specific seafood item, determine whether there is a difference in memory test scores between people who primarily eat one specific form of the seafood item in question (e.g. raw vs. canned vs. smoked vs. smoked vs. boiled vs. fried).

Conclusions

Seafood is an important food source and a significant part of the diets of many people around the globe. Therefore, it is essential to determine the potential impacts different seafood items have not only on physical health, but also cognitive functioning and memory. In this study, the group of participants who eat more fish than shellfish (group 1) did not have a significantly different mean test score from the group of participants who either eat equal amounts of fish and shellfish or more shellfish than fish (group 2), suggesting that diets relatively high in fish are neither positively nor negatively correlated with memory. However, the limitations of this study in combination with the various studies that contradict this study’s findings illustrate the need for further research. Through further research,

new resources, guidelines and governmental policies can be created to protect all members of the public from the potential negative effects on memory (and overall health) stemming from the various seafood items eaten around the globe.

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Competing Interest

The authors declare that they have no competing interests.