Sherry *Evo Edu Outreach* (2019) 12:19
https://doi.org/10.1186/s12052-019-0111-4

Evolution: Education and Outreach

RESEARCH ARTICLE Open Access

Does knowledge of evolutionary biology change high school students' attitudes about healthy eating?

Diana S. Sherry*

Abstract

Background: Embedded in the emerging area of evolutionary medicine is the premise that evolutionary biology can serve a pedagogical function with widespread applications for education and outreach. Although great strides have been taken over the decades by the science education community to improve evolution education in general, the knowledge gulf or gap between advances in evolutionary medicine and public understanding through the educational system has widened at a rapid pace—and not without consequences for public health, especially for young people. Epidemiological data indicate that the high rates of obesity and type-2 diabetes have begun to extend to adolescents and teenagers, an alarming trend of great concern. Would knowledge of the evolutionary biology perspective on diet and health have value for young people? Little is known about the efficacy of evolutionary medicine education as a public health outreach strategy. A small study was conducted at a New England high school and consisted of two research components: (1) a cross-sectional survey of students' views about what "healthy eating" means and (2) an intervention experiment designed to isolate exposure to knowledge of evolutionary biology. Data were collected through the use of questionnaires and analyzed according to qualitative methods.

Results: The survey results showed that students had an accurate view of general guidelines for healthy eating in alignment with public health messaging (e.g., avoiding junk food, eating lots of fruits and vegetables). The main result from the intervention experiment showed that students who received instruction in nutritional physiology alone did not change their view of what "healthy eating" means, whereas students who received instruction in nutritional physiology coupled with evolutionary biology changed their views of healthy food choices, leading to intended dietary changes.

Conclusions: A brief, one-time exposure to key concepts in evolutionary biology brought about a shift in students' perceptions of healthy eating. An approach that can cause a shift in perception or attitude, considered an essential first step toward effecting behavioral change, merits further attention and development. Evolutionary medicine education holds strong potential as an untapped yet effective public health outreach strategy regarding the dietary choices of youth.

Keywords: Evolutionary medicine, Evolution education, High school students, Public health outreach, Dietary choices, Healthy eating

Background

The emerging area of evolutionary medicine aims to connect principles of evolutionary biology to aspects of health to help elucidate the causes and consequences of disease as well as possible avenues for treatment and prevention. One premise embedded in the evolutionary medicine approach is that evolutionary biology can serve a pedagogical function with widespread applications for education and outreach. For example, recent efforts have been made to include evolutionary biology courses in medical school curricula and training programs (Nesse

*Correspondence: Diana_Sherry@emerson.edu
Institute of Liberal Arts, School of Communication, Emerson College, Boston, MA 02116, USA

and Schiffman 2003; Stearns et al. 2010; Nesse et al. 2010; Wells et al. 2017). At the undergraduate level, mostly in biology and anthropology departments at research universities, courses continue to spring up across the United States that focus on or integrate core concepts of evolutionary medicine (Omenn 2011; Grunspan et al. 2019).

At the high school level, great strides have been taken over the decades by the science education community to improve evolution education in general, including the establishment of state standards and the development of research protocols and instruments of measurement (Rutledge and Sadler 2007; Mead and Mates 2009; Smith et al. 2016), as well as curricular materials and activities/strategies for biology teachers (Branch and Scott 2008; Mead and Branch 2011; Graziose 2016; Pobiner et al. 2018). At the same time, statistics and polling data have shown that the knowledge "gulf" or "gap" between the science of evolution and public understanding of evolution through the educational system has persisted relatively unchanged (Rutledge and Warden 2000; Miller et al. 2006; Rosengren et al. 2012; Pobiner 2016); a sizeable portion (roughly a third or more) of Americans continues to have little understanding of evolution. Research has also indicated that the "educational divide" derives mainly from internal religious conflicts and sociocultural concerns that impede teaching and learning on the topic of evolution (Rutledge and Mitchell 2002; Berkman and Plutzer 2012). More recent initiatives to improve evolution education have explored ways to address this obstacle, such as classroom exposure to worldviews that demonstrate compatibility between religion and evolution (Barnes et al. 2017; Troung et al. 2018), and teaching strategies that encourage discussion and acknowledgment of students' religious concerns as a way to emphasize the scientific process and bypass the necessity of accepting evolution as the basis for learning the science of evolution (Bertka et al. 2019).

Although the educational inroads noted above have made use of human examples involving health to illustrate the relevance and validity of evolution (Beardsley et al. 2011; Meikle and Scott 2011; Moeller and Friedman 2018), the gulf between advances in evolutionary medicine and public understanding of this area through the educational system has widened at a rapid pace—and not without potential consequences for public health, especially for young people. One of the most pressing health problems of the 21st century is the current type-2 diabetes (T2D) epidemic. Well-documented epidemiologic trends have shown a steady increase in the prevalence of T2D, as well as other metabolic disorders, in the US (and worldwide) since the 1960s, along with a concomitant rise in the percent of the population considered overweight or obese, the leading known risk factor for developing T2D (Popkin 2009; Wells 2010; Willett 2013). Research has also shown that the high rates of overweight, obesity, and T2D have begun to extend to younger and younger age groups, including adolescents and teenagers (Cooper and Hagopian 2005; Ludwig 2007; Mancini 2009), an alarming trend of great concern. Furthermore, the Centers of Disease Control (CDC) report issued in October 2017 indicated that efforts to slow the trend have had little impact on the overweight and obesity rates of youth; young people are at greater risk than ever before.

Could knowledge of the evolutionary biology perspective on metabolic health have value for young people? Evolutionary biologists view the rising "diabesity" epidemic as a logical result of the interaction between ancestral physiology and contemporary environments (Lieberman 2003, 2013, Pollard 2008; Lindeberg 2012). Given that the human body was fashioned by natural selection to operate under ecological conditions very different from those we encounter today, the nutritional features of modern life, characterized by the consumption of high-caloric foods in the context of low physical activity levels, represent a radical departure from the formative ancestral past—with potential dire effects on metabolic health. Although a number of factors (genetic, psychological, sociological) can contribute to the likelihood of developing a metabolic disorder, the main factor is the way people eat (Cordain et al. 2005; Leonard 2007; Ulijaszek et al. 2012). Moreover, diabesity risk is not just a matter of surplus calories, but the type of foods consumed, namely carbohydrates, that can disrupt normal blood glucose regulation (Ludwig 2002; Gross et al. 2004; Sherry 2017). Would an understanding of the evolutionary medicine perspective on nutrition and health have an influence on the dietary choices of youth? Although little is known about the overall efficacy of knowledge of evolutionary biology itself as a public health prevention strategy, the use of evolution education as a means of public health outreach to teenagers is probably best positioned at the high school level, often the only formal evolution education many Americans receive.

Here, I report on a small evolutionary medicine intervention study conducted at a New England high school. As the principle investigator (PI), I set out to address two main questions: (1) Would nutritional information about carbohydrate metabolism at an advanced level have an impact on students' views about what "healthy eating" means? and (2) To what extent, if any, would the same nutritional information placed in the context of human evolutionary biology have an impact on students' views about healthy eating? I focused specifically on carbohydrate metabolism to increase students' awareness about the relationship between certain types of carbohydrates,

namely high glycemic foods and drinks, and weight gain. In addition, the study intentionally aimed to assess students' perceptions and views rather than behaviors because prior research has indicated that cognitive changes in attitudes and perceptions typically precede behavioral changes, especially when it comes to lifestyle factors such as diet and exercise (Braet and Van Winckel 2000; Hoffman et al. 2012). With this in mind, an education outreach approach that can potentially change teenagers' views of healthy eating could have long-term downstream significance. Habits formed in youth tend to become consolidated in later periods of life and weight gain in youth tends to carry the risk of remaining overweight into adulthood (Rolland-Cachera et al. 2006).

Methods and materials

Study sample and design

The study sample involved teenagers of both sexes ranging from 15 to 17 years old enrolled in a public high school in the city of Cambridge, MA. The school maintains a diverse student population at approximately 29.1% African American, 11.0% Asian, 14.2% Hispanic and 38.0% White according to enrollment history data from the Massachusetts Department of Education. At the time of this study, 39.3% of the student population qualified for free/reduced lunch assistance. Procedures for the study were approved by the principal and superintendent of the participating school. Conducted in collaboration with the AP biology teacher, the study was arranged to coincide with the nutrition unit of the biology class in spring 2012. Students were invited to participate, in part, as an opportunity to gain hands-on experience with the scientific process. The PI described the study in a presentation to the class, answered students' questions, and distributed a written invitation that included the project description, the informed consent certificate, and the stated purpose of the study as follows: "You are invited to take part in this study because your thoughts/views can contribute much to our understanding of factors that influence food choices at the high school level." Participation was entirely voluntary. Students could stop at any time and all written responses would remain anonymous. Of the nineteen students enrolled in the AP biology class, eighteen [nine males (m) and nine females (f)] signed up to participate and were accepted, provided that they obtained their parent or guardian's signature on the consent form.

The study design consisted of two components: (1) a cross-sectional survey of students' views about what "healthy eating" means and (2) an intervention experiment designed to isolate exposure to knowledge of human evolutionary biology, whereby two groups of nine students (ethnically diverse and matched for age and sex composition as closely as possible) were randomly assigned to attend one of two nutrition workshops for approximately an hour. Group A received instruction in nutritional physiology alone, including glucose/insulin dynamics, glucose homeostasis, and the relationship between glucose regulation and health, as well as the glycemic index (and load) of common foods. Group B received the same areas of instruction coupled with human evolutionary biology, namely glucose regulation in the context of a hunter-gatherer ancestral past. The PI made every effort to present these areas of instruction with equal enthusiasm during both workshops.

In advance of the workshop, each participant was given a brief (four-page) reading assignment/handout and asked to keep all materials and discussions confidential until the project was completed. Group A's handout, "Carbohydrates Up Close And Personal" based on the book *Eat*, *Drink*, *and Be Healthy* (2001) by Walter C. Willett, M.D., summarized the areas of nutritional physiology noted above and included a table listing the glycemic index of common foods and drinks. Group B's handout, "The Way We Eat Now" based on a Harvard Magazine (2004) article by Craig Lambert, presented the same information about nutritional physiology along with the appended table, but also contained an evolutionary biology perspective: "ancient bodies and genes can collide with modern lifestyles and technology," giving rise to such health problems as obesity and diabetes.

The workshops for both groups were designed to emphasize key common content areas from the reading, and also give students an opportunity to discuss topics of most interest to them. The PI, for example, used the whiteboard to graph a visual depiction of glucose/insulin dynamics following a carbohydrate-based meal and asked both groups the same set of discussion questions (e.g., "What do you think happens to the 'extra' glucose once glycogen stores are replenished?" and "What surprises you most about the glycemic index of common foods?"). Group B received additional instruction, however, in human evolutionary biology. The PI used the whiteboard to introduce the concept of "deep time" and illustrate the main branching sequences on the "tree of life" leading to modern humans. This visual depiction reinforced the idea that human nutritional physiology evolved over millions of years in the context of a hunter-gatherer way of life and that agriculture, industrialized food products, and sedentary lifestyles are relatively recent phenomena.

Although the nutrition workshops were arranged to take place on 2 consecutive days during biology class (on site at the school in a location separate from the biology classroom), not all students were present on the day of their assigned workshop. One student from each group was absent from biology class that day and one student

from each group decided not to participate on the day of the workshop. Furthermore, two students from Group B were not able to attend due to an unexpected change in their athletic travel schedule. For these reasons, the final study sample for the intervention component consisted of seven students (four females and three males) for Group A and five students (three females and two males) for Group B. Sample size remained within the acceptable range for small group qualitative research, as described below.

Data collection and analysis

To ascertain students' views about diet and health, descriptive data were collected based on qualitative methods and the use of questionnaires. Thoughts and perceptions do not readily lend themselves to quantification and the qualitative approach allows researchers to identify attitudes, perceptions and meanings relevant to the study from the perspective of the participants (Holloway 2005; Flick 2006). This study used methods to facilitate the goal of giving each participant a "voice" that is documented and analyzed by the researcher based on a small group discussion of a pre-defined topic, framed by the aims of the study and stimulated by prepared material. In this context, as well as in collaborative learning tutorials, group size tends to be small with eight as the preferred maximum and five as the optimal number of participants (Wibeck et al. 2007; Bertka et al. 2019). Questionnaires consisted mostly of discursive, open-ended questions so that students could freely express their thoughts in response to the prompts. Students were also informed that there were no right or wrong answers.

The cross-sectional survey questionnaire was administered at the start of biology class the week before the scheduled nutrition workshops and collected data on students' views of "healthy eating" and perceptions of their own diet; the two discursive questions and their aims in the study are listed in Box 1. For the intervention component of the study, two separate questionnaires were administered. The first questionnaire was distributed and filled out at the start of each workshop and contained questions designed to identify students' baseline knowledge and familiarity with the content of the reading assignment; the questions and their aims in the study are listed in Box 2. The second questionnaire was administered at the end of the workshop and contained questions designed to identify perceived benefits from the discussion-workshop session; the questions and their aims in the study are listed in Box 3.

Data from the questionnaires were analyzed based on methods described previously by Barco Leme et al. (2011) according to the following three steps: (1) each question was analyzed separately; (2) key expressions—defined as the most significant content areas, phrases or excerpts—were identified and extracted from every student response to a given question; (3) key expressions that conveyed the same or a similar/complementary meaning were then grouped into distinct categories to identify the central ideas. Central ideas, therefore, represent a culmination and synthesis of all the descriptive content data generated from the key expressions contained in students' responses to a given question. Results are reported for each discursive question in terms of the central ideas identified in rank order of descending frequency (%) based on the total number of key expressions (TKE) generated for the question.

Box 1: Cross-sectional survey questionnaire

1. In your opinion, what does "healthy eating" mean?

Aim: to identify the student's perceptions of healthy eating.

2. Do you consider your diet healthy? Why or Why not?

Aim: to identify the student's self-assessment of their diet.

Box 2: Workshop reading assignment questionnaire

1. What knowledge did you already possess prior to reading the material for today?

Aim: to identify content areas familiar to the student.

2. What new knowledge or information did you gain from the reading?

Aim: to identify content areas unfamiliar to the student.

3. What would you like to know more about (or most like to talk about) today?

Aim: to identify content areas of interest to the student.

4. For the following statements, please circle the choice that best applies to you:

I was able to read: all—about half—some—none—of the reading for today.

I would describe the reading for today's discussion as:

too easy—somewhat easy—fine—somewhat difficult—too difficult

Aim: to identify the student's level of engagement with the reading material.

Box 3: Post-workshop questionnaire

1. What main insight did you gain from today's discussion?

Aim: to identify the student's perceived content value of the workshop.

2. Did your view of what "healthy eating" means change at all as a result of today's discussion? If so, how exactly?

Aim: to identify any reassessment of the student's perception of "healthy eating."

3. What sort of actions might you take as a result of today's discussion?

Aim: to identify any intended behavioral changes motivated by the workshop.

4. For the following statement, please circle the choice that best applies to you:

I would describe today's discussion as:

very beneficial—somewhat beneficial—not especially beneficial—not beneficial at all

Aim: to identify the student's perceived level of benefit from the workshop.

5. Any final comments or thoughts?

Aim: to give the student an opportunity for open-ended commentary.

Results

Cross-sectional survey

The first survey question "In your opinion, what does 'healthy eating' mean?" generated 98 key expressions in total and four central ideas (Table 1). Two broad conceptual ideas emerged: (1) maintaining a balanced and/or varied diet (with the food pyramid and major food groups mentioned occasionally as guidelines), and (2) control over the intake of calories and/or food portions. Together, these two central ideas accounted for 61.3% of total key expressions (TKE). The other two central ideas focused on specific "do's and don'ts" of healthy eating by either avoiding or including particular types of food in the diet. Foods to avoid included fast food, sweets/sugar, junk food, fried food and fat, whereas foods to include consistently emphasized fruits and vegetables. Together, these two central ideas accounted for 29.6% TKE. The remaining 9.1% TKE noted the importance of drinking water, individual lifestyle factors, and avoiding food contamination.

Table 1 Central ideas and corresponding proportion (%) of total key expressions generated in response to the first survey question on what "healthy eating" means

1. A balanced and/or varied diet	37.8%
2. Calorie and/or portion control	23.5%
Subtotal (broad concepts)	61.3%
3. Avoiding certain foods	18.4%
4. Including certain foods	11.2%
Subtotal (specific "do's and don'ts")	29.6%
5. Other	9.1%

Results for the second survey question "Do you consider your diet healthy? Why or why not?" are summarized in Table 2. Most students considered their diet to be healthy overall (61.1% or n = 11; 5 m/6f). The remaining third (33.3% or n = 6; 3 m/3f) considered their diet to be either somewhat healthy or not healthy (n = 4; 2 m/2f and n = 2; 1 m/1f respectively); one student did not know. There were no sex differences between the students' self-assessment categories.

Although both categories yielded the same set of central ideas as the first survey question, greater emphasis was placed on specific food choices in the context of self-assessment. Students who described their diet as healthy overall generated 28 total key expressions; 53.6% TKE fell along the lines of specific "do's and don'ts" about particular foods (avoiding junk/fast food, sweets/candy, soda/juice and red meat, and/or including fruits and vegetables); 35.7% TKE identified the broad concepts of a balanced/varied diet and calorie/portion control; the remaining 10.7% TKE noted the importance of drinking water. Students who described their diet as somewhat or not healthy generated 15 total key expressions; although 46.5% TKE identified the broad concepts of a balanced/varied diet and calorie/portion control, 40.0% TKE identified either avoiding and/or including certain types of food in the diet (avoiding sweets, eating fruit, too much fat/sugar, not enough vegetables) as the basis for self-assessment; the remaining 13.5% TKE mentioned

Table 2 Central ideas and corresponding proportion (%) of total key expressions generated in response to the second survey question on self-assessment of diet

	Healthy (%)	Somewhat/not healthy (%)
1. A balanced and/or varied diet	17.85	33.0
2. Calorie and/or portion control	17.85	13.5
Subtotal (broad concepts)	35.7	46.5
3. Avoiding certain foods	28.6	20.0
4. Including certain foods	25.0	20.0
Subtotal (specific "do's and don'ts")	53.6	40.0
5. Other	10.7	13.5

drinking water and food allergies. In addition, the student who did not categorize his diet stated that he didn't know if he was "getting enough fruits and vegetables, water, grain."

Intervention experiment: reading assignment questionnaire

Results pertaining to the content of the reading assignment are summarized for Group A in Table 3. The first question "What knowledge did you already possess prior to reading the material for today?" generated 25 total key expressions and five central ideas. Students were most familiar with the idea that carbohydrates come in different forms (e.g., "simple and complex" and "sugars and starches"), and were somewhat familiar with the idea that blood sugar refers to glucose traveling in the bloodstream. Together, these two central ideas accounted for 68.0% TKE. Students were slightly familiar with common foods that contain carbohydrates (e.g., bread, rice, pizza, fries, and soda) and the role of insulin to "balance blood sugar levels"; each of these ideas accounted for 12% TKE. Students were least familiar with the relevance of carbohydrate metabolism for health, accounting for 8.0% TKE.

The second question "What new knowledge or information did you gain from the reading?" generated 22 total key expressions and three ideas, two of which dominated the students' responses: (1) carbohydrates can enter the bloodstream as glucose at different rates—with consequences for health, and (2) the glycemic index measures this capacity in food. Together, these two central ideas accounted for 91.0% TKE. The remaining 9.0% TKE identified the role of insulin and the pancreas to regulate blood sugar.

The question "What would you like to know more about (or most like to talk about) today?" generated 14 total key expressions and one prominent central idea: the health consequences of dietary choices, especially the "impact of carbs" on "disease" (including diabetes, obesity, breast cancer, and possible effects on the brain), accounting for 71.4% TKE. The other 28.6% of total key expressions identified diverse interests (e.g., "Where does fat end up?" and "What are empty calories?"). Students who had completed the reading assignment found the level either "fine" (n = 3) or "easy" (n = 2); students who had completed "some" of the reading found the level "somewhat difficult" (n = 2).

Results pertaining to the content of the reading assignment for Group B are summarized in Table 4. The first question "What knowledge did you already possess prior to reading the material for today?" generated 12 total key expressions and three central ideas. Students were most familiar with the idea that overweight/obesity is a serious problem in the United States, accounting for 75.0% TKE. Students were somewhat familiar with the idea that carbohydrates come in different forms (e.g., "complex and simple sugars"), accounting for 16.7% TKE. The remaining 8.3% TKE identified knowing that "people have a taste preference for sweets."

The second question "What new knowledge or information did you gain from the reading?" generated 17 total key expressions and five ideas. Students identified the *extent* of the overweight/obesity problem as new information, describing the statistical projections as "shocking" and "alarming"; this central idea accounted for 35.3% TKE. Three other ideas focused on aspects of carbohydrate metabolism along similar lines as Group A: (1) some foods can raise blood sugar levels quickly (even foods that "don't taste sugary" such as cornflakes, bread, pasta, and pancakes), and (2) the glycemic index measures this capacity in food, and (3) blood sugar levels need to be regulated by the body. Together, these three central ideas accounted for 58.7% TKE. Notably, the remaining 5.9% TKE identified the context of human evolution as new information.

Table 3 Central ideas and corresponding proportion (%) of total key expressions for Group A in response to content questions about the reading assignment

Familiar content areas	
1. Carbohydrates come in different forms	44.0%
2. Blood sugar refers to glucose	24.0%
3. Foods that contain carbohydrates	12.0%
4. The role of insulin	12.0%
5. Relevance of carbohydrates to health	8.0%
Unfamiliar or new content areas	
1. Glucose can enter the bloodstream at different rates	45.5%
2. The glycemic index as a metric	45.5%
3. The role of insulin and the pancreas	9.0%

Table 4 Central ideas and corresponding proportion (%) of total key expressions for Group B in response to content questions about the reading assignment

Familiar content areas	
1. Overweight/obesity is a serious problem	75.0%
2. Carbohydrates come in different forms	16.7%
3. People have a taste preference for sweets	8.3%
Unfamiliar or new content areas	
1. The *extent* of the overweight/obesity problem	35.3%
2. Some foods can raise blood sugar levels quickly	23.5%
3. The glycemic index as a metric	17.6%
4. Blood sugar levels need to be regulated	17.6%
5. The context of human evolution	5.9%

The question "What would you like to know more about (or most like to talk about) today?" generated 17 total key expressions and four ideas. Students mostly wanted to know more about glucose regulation (namely the insulin response based on the glycemic index), accounting for 58.8% TKE. Students mostly wanted to *talk* about "solutions" to the overweight/obesity problem, accounting for 23.5% TKE. An additional idea focused on wanting to know more about human evolution, accounting for 11.8% TKE. The remaining 5.9% TKE brought up the role of exercise. Students who had completed the reading assignment found the level "somewhat easy" (n = 2) and "somewhat difficult" (n = 1); students who had completed "about half" of the reading found the level "fine" (n = 1) and "somewhat difficult" (n = 1).

Post-workshop questionnaire

Results pertaining to the nutrition workshops indicated one prominent similarity and two major differences between Group A and Group B. The first question "What main insight did you gain from today's discussion?" generated the same central idea for both study groups: Most students from Group A (n = 4) and all students from Group B (n = 5) responded along similar lines that foods with a "high glycemic index" can be "harmful over time." One student (from Group A) added "it [the glycemic index] should be on food labels and actually be discussed in the world so everybody knows what it is just like how they know what calories and fat are." Two students from Group A identified as their main insight understanding "the why" and "inclination" people have to eat "certain foods," and one student did not answer the prompt. Notably, one student from Group B added that the evolutionary context of "hunter-gatherers" was a second new insight gained from the workshop.

The second question "Did your view of what 'healthy eating' means change at all as a result of today's discussion? If so, how exactly?" generated a clear difference between the two study groups. As shown in Fig. 1, *none* of the students from Group A responded that their view of healthy eating had changed, whereas *all* of the students from Group B responded that their view of healthy eating had changed as a result of the nutrition workshop. Moreover, whereas the comments from Group A acknowledged an increased awareness about nutrition in general and the glycemic index, in particular, the comments from Group B underscored the cognitive shift in perception:

- "Yes! It changed my mind about healthy eating in a good way."
- "Yes! In thirty minutes I was able to look at such an important subject in a completely different way."
- "Yes, it did."

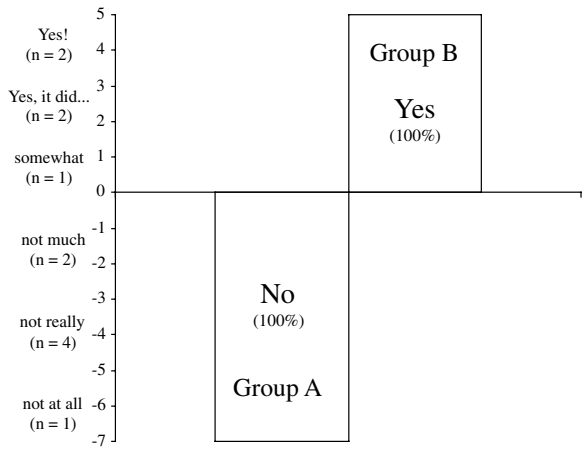

Fig. 1 Comparison of student responses to the question "Did your view of what 'healthy eating' means change at all as a result of today's discussion?" for the two study groups. All responses from Group A fell into the "no" category after receiving instruction in nutritional physiology alone, whereas all responses from Group B fell into the "yes" category after receiving instruction in nutritional physiology coupled with human evolutionary biology

- "Healthy eating has actually become a completely different concept because of today."
- "My view of healthy eating has changed somewhat. I will stay on track more."

One student from Group B also commented on the workshop approach used in the study: "It seems that teens especially are subject to lectures about nutrition, but it doesn't really seem to be working. I think that this study provides a more effective way to open up the discussion about nutrition with kids."

The third question "What sort of actions might you take as a result of today's discussion?" generated another clear difference between the two study groups. Group A identified three types of possible action: (1) no action ("To be honest, I probably will continue to eat as I've always eaten" and "to keep maintaining a balanced diet" and "none"; n = 3), and (2) outreach to others about the glycemic index ("I might explain GI to people" and "it would be important to let other teens know [about GI]"; n = 2), and (3) paying more attention to personal dietary choices ("to think more about the foods I am eating" and "I probably will be more careful about eating food with a low glycemic index because it is healthier"; n = 2). In contrast, *all* students from Group B identified *one* type of possible action: paying more attention to personal dietary choices, expressed for the most part in the form of declarative "I will" statements regarding specific intentions:

- "I will think especially about what I'm eating for breakfast."
- "I will try to cut down on starches."
- "I'll start to balance my meals more."
- "I will start eating more fruit to keep myself at a good glycemic level."
- "An action that I would take is monitoring food I actually eat in a day and how I can change that to be more healthy."

In terms of rating the nutrition workshop, students from Group A rated the workshop as "somewhat beneficial" (n = 6), and one student did not answer the prompt. Students from Group B rated the workshop as either "somewhat beneficial" (n = 3) or "very beneficial" (n = 2). One student from Group A offered a final comment ("Thanks for the opportunity to participate and learn!"), whereas nearly all students (n = 4) from Group B offered a final comment. Three comments expressed a desire to learn more ("can't wait to learn more to keep myself healthy" and "wondering about physical activity" and "I want to learn more about hunter-gatherers and what humans are designed to eat and do.") The remaining comment from Group B took the form of a thank you: "Thank you so much for teaching us this and allowing us to discuss it. I really think that this has the ability to alter the health of our generation, even if in a tiny way."

Discussion

Summary of results

Results from the survey component of the study showed that the high school students in this sample had an accurate view of general guidelines for healthy eating in alignment with public health messaging. For example, students viewed eating a balanced and varied diet and keeping caloric intake and portions under control as fundamental to healthy eating. In the context of self-assessment, students' criteria moved slightly away from broad principles to an emphasis placed on the consumption of specific foods. For example, students identified avoiding the usual culprits (junk food, fast food, fried food and sweets) and eating lots of fruits and vegetables as part of a healthy diet.

Although students did not mention carbohydrates in the survey results, the reading assignment results indicated a familiarity with basic nutritional information about carbohydrates, as well as an overall awareness of the overweight and obesity problem. The reading assignment results also demonstrated that the information on carbohydrate metabolism, including the relationship between glucose/insulin dynamics and health, was a new content area for students in both discussion groups, eliminating this as a potential confound. The glycemic index, in particular, made a strong impression on students.

In light of the finding that students in both study groups considered the new nutritional information beneficial, it would be reasonable to expect this instruction to have had an effect on students' views of healthy eating, perhaps prompting some students to reassess their diet given the knowledge gained about carbohydrate metabolism and health. However, this was not the case. Only students who had also received instruction in evolutionary biology changed their view of healthy eating. Although sample size was small, this striking result was unambiguous and substantiated further by students' statements about intended actions regarding specific changes to their diet. Taken together, the findings from the discussion-workshop intervention showed that the new nutritional information was necessary but not sufficient to change students' perceptions of healthy eating; the context of human evolutionary biology was also required.

Implications

Although this study needs to be replicated with a larger sample size, along with a follow-up phase to address the extent to which students acted on their intended dietary changes, the main result suggests nonetheless that knowledge of evolutionary biology contains a powerful psychological dimension and begs the question: *why* would knowledge of evolutionary biology generate a different experience for students receiving the same nutritional information? It seems extraordinary that a brief, one-time exposure to key concepts in evolutionary biology can bring about a shift in students' perceptions of healthy eating, especially considering that students for the most part did not explicitly attribute this shift to the evolutionary biology component of the instruction; only one student referred to the hunter-gatherer legacy in responses and comments.

It becomes fascinating to consider various explanations for why knowledge of evolutionary biology was an effective intervention strategy in this study. According to previous research, the pedagogical value of relating evolution to contemporary topics in the everyday life of humans, such as health, probably played an important role (Nettle 2010; Pobiner 2012). Another possible insight comes from the student who referenced the hunter-gatherer ancestral past and also repeatedly used the word "logic." Could it be that knowledge of evolutionary biology bestows a sense of intellectual satisfaction or appeal based on logic? Certainly, an explanatory framework grounded in evolutionary logic might make guidelines about healthy eating seem less arbitrary and more

rational than nutritional information alone. In addition, an understanding of evolutionary logic might translate readily into a form of self-empowerment, one that supersedes the authoritarian prescripts that often accompany lectures on health and nutrition for youth, allowing young people to take specific actions related to diet and health tailored to their own individual circumstances. With this in mind, knowledge of evolutionary biology combined with nutritional information might increase the degree of self-efficacy, an intrinsic capacity that tends to facilitate and promote successful changes in lifestyle behaviors (Bandura 1977; Strecher et al. 1986; Sheeran et al. 2016).

The value of an approach that can cause a shift in perception or attitude is especially promising and relevant for an intervention strategy because a shift in perception is generally considered an essential first step or psychological precursor toward effecting behavioral change (Braet and Van Winckel 2000; Hoffman et al. 2012). Yet this is notoriously difficult to do. For example, research has shown that once people view their diet as healthy, about 40–70% claim that a change in food choice is not necessary (Barco Leme et al. 2011). The findings reported here for Group A also illustrate the difficulty in that the new nutritional information, while deemed beneficial, did not translate into a reassessment of dietary choices or a revision of what healthy eating means. Any approach that has the capacity to increase the probability of changing perception (in this case about healthy eating), and thereby accomplish step one toward behavioral change, merits further attention and development.

Regardless of the underlying reasons for the cognitive appeal of human evolutionary biology, the results have a number of implications for education and outreach efforts. First, the evolutionary biology dimension of health and nutrition didn't stand out from the reading alone; it required the discussion-workshop to come to the fore. The pedagogical value of the workshop setting described here, characterized by an interactive presentation, accords well with recent research showing that the use of invited speakers or presenters can be an effective general practice for evolutionary biology education and outreach (e.g., Barnes et al. 2017). The use of an invited speaker has the advantage of reducing the burden and reliance on the regular classroom teacher and bypassing any potential ambivalence the teacher may have about the topic of evolution. Second, the pedagogical importance of linking broad nutritional concepts to specific foods seems to be a prominent take-away message (and likely explains the impact of the glycemic index). Such an approach gives young people a concrete way to apply nutritional information to real-world contexts and makes it possible to take personal responsibility for food choices when feasible. The glycemic index, in particular, offers an excellent teaching tool in this regard because of the direct connection between insulin/glucose dynamics and specific foods.

Third, the main result reported here adds to the growing recognition that explicitly addressing the question of belief or acceptance of evolution may not be necessary to deliver an effective public health message grounded in evolutionary biology. The intervention strategy used in this study may have precipitated a change in perception in part precisely because acceptance of evolution was not the focus or "goal" of the workshop, perhaps minimizing the degree of internal conflict with religious beliefs. In light of these implications, development of education outreach materials along the lines noted above for implementation and dissemination would be a next step, especially combined with continued research. Avenues for dissemination could interface with existing infrastructures including schools, museums, and professional societies that often have evolution education outreach programs (see Pobiner 2016).

It is important to acknowledge that nutritional information may not be the main determinant of food choices in adolescents; other factors include "hunger/cravings, convenience, availability, parental and peer influence (Barco Leme et al. 2011: 1040)." In other words, a complex array of societal and cultural forces influences the dietary choices of youth (Nelson et al. 2006). Furthermore, nutritional guidelines promulgated by governmental agencies, health associations (e.g., American Heart Association, American Diabetes Association, etc.) and the food and marketing industry are susceptible to conflicts of interest and/or a singular focus (Popkin 2009). Given that structural reforms such as independent assessments by the scientific community are not likely to take hold anytime soon, individual empowerment presents a reasonable alternative. Ultimately, people make choices within the sociocultural parameters of their lives. Policies that emphasize self-efficacy or self-reliance have long been recognized by developmental agencies, including the World Health Organization (WHO), as beneficial not only in terms of reducing nutritional health inequalities, but also in terms of disease control, education and health promotion (Ulijaszek et al. 2012).

Expanding the scope of public health intervention strategies to include evolution education outreach provides another avenue of potential benefit to young people, who deserve to have the opportunity to make logical, informed choices about their health and lifestyle behaviors.

Conclusion

The qualitative data presented here adds to the general understanding of what "healthy eating" means from the perspective of high school students based on discursive, open-ended questionnaires. In addition, students recruited from a biology class were randomly assigned to attend one of two nutrition workshops designed to isolate the effects of exposure to knowledge of evolutionary biology as a possible public health intervention strategy. Although sample size was small, the main result showed that students who received instruction in nutritional physiology coupled with key concepts in human evolutionary biology changed their perceptions of healthy eating, with the intention of implementing precise dietary changes immediately. These findings suggest that evolutionary medicine education holds strong potential as an untapped yet effective public health outreach strategy regarding the dietary choices of youth.

Abbreviations

AP: advanced placement; CDC: Centers of Disease Control; GI: glycemic index; PI: principle investigator; T2D: type-2 diabetes; TKE: total key expressions; WHO: World Health Organization.

Acknowledgements

I thank Peter Ellison, Dan Lieberman, Meg Lynch and the Department of Human Evolutionary Biology at Harvard University for sponsoring this project. Many thanks also to Paul McGuinness, Sarah Kariko, Laura Leibensperger, and Chase Finn for their assistance and to Allan Gehant and Carolyn Turke for permission to conduct this research. I am grateful to two anonymous reviewers for their helpful comments and suggestions on an earlier version of the manuscript.

Authors' contributions

The author read and approved the final manuscript.

Funding

Not applicable.

Availability of data and materials

The qualitative data from this study are not being made publically available in order to protect the identity of the students.

Ethics approval and consent to participate

All appropriate approvals and signed informed consent forms were obtained.

Consent for publication

Not applicable.

Competing interests

The author declares no competing interests.

Received: 30 July 2019 Accepted: 5 November 2019
Published online: 14 November 2019

References

Bandura A. Self-efficacy: toward a unifying theory of behavioral change. Psychol Rev. 1977;84(2):191–215.

Barco Leme AC, Philippi ST, da Silva ECT. Association of Brazilian adolescents with healthy eating: knowledge, perceptions and food choices. Food Nutr Sci. 2011;2:1036–42.

Barnes ME, Elser J, Brownell SE. Impact of a short evolution module on students' perceived conflict between religion and evolution. Am Biol Teach. 2017;79(2):104–11.

Beardsley PM, Stuhlsatz MAM, Kruse RA, Eckstrand IA, Gordon SD, Odenwald WF. Evolution and medicine: an inquiry-based high school curriculum supplement. Evol Educ Outreach. 2011;4(4):603–12.

Berkman M, Plutzer E. An evolving controversy: the struggle to teach science in science classes. Am Educ. 2012;36(2):12–40.

Bertka CM, Pobiner B, Beardsley P, Watson WA. Acknowledging students' concerns about evolution: a proactive teaching strategy. Evol Educ Outreach. 2019;12:3.

Braet C, Van Winckel M. Long-term follow-up of a cognitive-behavioral treatment program for obese children. Behav Ther. 2000;31:55–74.

Branch G, Scott EC. Overcoming obstacles to evolution education: in the beginning. Evol Educ Outreach. 2008;1:53–5.

Cooper EB, Hagopian W. Obesity at the onset of diabetes in an ethnically diverse population of children: what does it mean for epidemiologists and clinicians? Pediatrics. 2005;115(5):e553–60.

Cordain L, Eaton BE, Sebastian A, Mann N, et al. Origins and evolution of the Western diet: health implications for the 21st century. Am J Clin Nutr. 2005;81:341–54.

Flick U, editor. An introduction to qualitative research. 3rd ed. Thousand Oaks: Sage; 2006.

Graziose MM. Why do we choose certain foods? Am Biol Teach. 2016;78(1):62–6.

Gross LS, Li L, Ford ES, Liu S. Increased consumption of refined carbohydrates and the epidemic of type 2 diabetes in the United States: an ecological assessment. Am J Clin Nutr. 2004;79:774–9.

Grunspan DZ, Moeller KT, Nesse RN, Brownell S. The state of evolutionary medicine in undergraduate education. EMPH. 2019;1:82–92.

Hoffman SG, Asnaani A, Vonk IJJ, Sawyer AT, Fang A. The efficacy of cognitive behavioral therapy: a review of meta-analyses. Cognit Ther Res. 2012;36(5):427–40.

Holloway I, editor. Qualitative research in health care. New York: Open University Press; 2005.

Lambert CA. The way we eat now. Harv Mag. 2004;106(5):50–8.

Leonard WR. Lifestyle, diet and disease: comparative perspectives on the determinants of chronic health risks. In: Stearns SC, Koello JC, editors. Evolution in health and disease. 2nd ed. Oxford: Oxford University Press; 2007.

Lieberman LS. Dietary, evolutionary, and modernizing influences on the prevalence of type 2 diabetes. Annu Rev Nutr. 2003;23:345–77.

Lieberman DE. The story of the human body: evolution, health, and disease. New York: Pantheon Books; 2013.

Lindeberg S. Paleolithic diets as a model for prevention and treatment of western disease. Am J Hum Biol. 2012;24:110–5.

Ludwig DS. The glycemic index: pathophysiological mechanisms relating obesity, diabetes, and cardiovascular disease. JAMA. 2002;287:2414–23.

Ludwig DS. Childhood obesity—the shape of things to come. N Engl J Med. 2007;357(23):2325–7.

Mancini MC. Metabolic syndrome in children and adolescents—criteria for diagnosis. Diabetol Metab Syndr. 2009;1:20–3.

Mead LS, Branch G. Overcoming obstacles to evolution education: why bother teaching evolution in high school? Evol Educ Outreach. 2011;4(1):114–6.

Mead LS, Mates A. Why science standards are important to a strong science curriculum and how states measure up. Evol Educ Outreach. 2009;2:359–71.

Meikle WE, Scott EC. Evolutionary medicine: a key to introducing evolution. Evol Educ Outreach. 2011;4(4):644–7.

Miller J, Scott E, Okamoto S. Public acceptance of evolution. Science. 2006;313:765–6.

Moeller K, Friedman M. Evolutionary medicine in the classroom using health to teach evolution. Sci Teach. 2018;86(4):18–20.

Nelson MC, Gordon-Larsen P, Song Y, Popkin BM. Built and social environments: associations with adolescent overweight and activity. Am J Prev Med. 2006;31(2):109–17.

Nesse RM, Schiffman JD. Evolutionary biology in the medical school curriculum. Bioscience. 2003;53(6):585–7.

Nesse RM, Bergsrom CT, Ellison PT, et al. Making evolutionary biology a basic science for medicine. Proc Natl Acad Sci. 2010;107(Suppl 1):1800–7.

Nettle D. Understanding of evolution may be improved by thinking about people. Evol Psychol. 2010;8:205–28.
Omenn GS. Enhancing the teaching of evolution in public health. Evol Educ Outreach. 2011;4:567–73.
Pobiner BL. Use human examples to teach evolution. Am Biol Teach. 2012;74(2):71–2.
Pobiner B. Accepting, understanding, teaching and learning (human) evolution: obstacles and opportunities. Yearb Phys Anthropol. 2016;159:S232–74.
Pobiner B, Beardsley P, Bertka CM, Watson W. Using human case studies to teach evolution in high school biology classrooms. Evol Educ Outreach. 2018;11:3.
Pollard TM. Western diseases: an evolutionary perspective. Cambridge: Cambridge University Press; 2008.
Popkin BM. The world is fat: the fads, trends, policies, and products that are fattening the human race. New York: Avery; 2009.
Rolland-Cachera MF, Deheeger M, Maillot M, Bellisle F. Early adiposity rebound: causes and consequences for obesity in children and adults. Int J Obes. 2006;30:S11–7.
Rosengren KS, Brem SK, Evans ME, Sinatra GM, editors. Evolution challenges: integrating research and practice in teaching and learning about evolution. New York: Oxford University Press; 2012.
Rutledge ML, Mitchell MA. High school biology teachers' knowledge structure, acceptance and teaching of evolution. Am Biol Teach. 2002;64(1):21–8.
Rutledge ML, Sadler KC. Reliability of the measure of acceptance of the theory of evolution (MATE) instrument with university students. Am Biol Teach. 2007;69(6):332–5.
Rutledge ML, Warden MA. Evolutionary theory, the nature of science & high school biology teachers: critical relationships. Am Biol Teach. 2000;62(1):23–31.
Sheeran P, Maki A, Montanaro E, Avishari-Yitshak A, Bryan A, Klein WMP, Miles E, Rothman AJ. The impact of changing attitudes, norms, and self-efficacy on health-related intentions and behavior: a meta-analysis. Health Psychol. 2016;35(11):1178–88.
Sherry DS. From novel to extreme: contemporary environments and physiologic dysfunction. In: Jasienska G, Sherry DS, Holmes DJ, editors. The arc of life: evolution and health across the life course. New York: Springer Nature; 2017. p. 177–93.
Smith MU, Snyder S, Devereaux RS. The GAENE-generalized acceptance of evolution evaluation: development of a new measure of evolution acceptance. J Res Sci Teach. 2016;53:1289–315.
Stearns SC, Nesse RM, Govindaraju DR, Ellison PT. Evolution in health and medicine Sackler colloquium: evolutionary perspectives on health and medicine. Proc Natl Acad Sci. 2010;107(Suppl 1):1691–5.
Strecher VJ, DeVellis BM, Becker MH, Rosenstock IM. The role of self-efficacy in achieving health behavior change. Health Educ Q. 1986;13:73–91.
Troung JM, Barnes ME, Brownell SE. Can six minutes of culturally competent evolution education reduce students' level of perceived conflict between evolution and religion? Am Biol Teach. 2018;80(2):106–15.
Ulijaszek SJ, Mann N, Elton S. Evolving human nutrition: implications for public health. Cambridge: Cambridge University Press; 2012.
Wells JCK. The evolutionary biology of human body fatness: thrift and control. Cambridge: Cambridge University Press; 2010.
Wells JCK, Nesse RM, Sear R, Johnstone RA, Stearns SC. Evolutionary public health: introducing the concept. Lancet. 2017;390(10093):500–9.
Wibeck V, Abrandt DM, Oberg G. Learning from focus groups: an analytical dimension for enhancing focus group research. Qual Res. 2007;72(2):249–67.
Willett WC. Eat, drink, and be healthy: the Harvard medical school guide to healthy eating. New York: Simon and Schuster; 2001.
Willett W. Nutritional epidemiology. 3rd ed. Oxford: Oxford University Press; 2013.

Publisher's Note