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Effects of a Typical Fast-Food Meal on Arterial Stiffness in Young Adults

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Research Article

Effects of a Typical Fast-Food Meal on Arterial Stiffness in Young Adults

—Erik J. Harrington

By contributing to poor eating habits, fast-food chains play a large role in the obesity epidemic and its related health problems in the United States. It is known that a diet high in fat, sodium, and cholesterol (which describes most fast-food options) increases the risk of developing cardiovascular-related health complications (Anderson et al. 2011). One of these is greater arterial stiffness, or a decrease in the ability of the arteries to constrict and relax to move blood efficiently.

Arterial stiffness affects every single person as they age (Greenwald 2007). As a kinesiology: exercise science major at the University of New Hampshire (UNH), I am interested in the short-term effects of fast-food meal consumption because of this topic's application to the general public. This important information is something that can benefit everyone, not just athletes. I was able to study these physiological changes after applying for and receiving a Summer Undergraduate Research Fellowship (SURF) through the Hamel Center for Undergraduate Research. My research focused on how arterial stiffness is affected by a fast-food meal high in fat, sodium, and cholesterol.

The author, Erik Harrington

When consumed infrequently, meals of this nature are not a problem. However, 83 percent of American consumers report that they dine at fast-food restaurants at least once per week (Vikraman, Fryar, and Ogden 2015). With 34 percent of young adults consuming fast food at least once a day, this industry has the potential to influence what the average American chooses to eat. With McDonald's making 21 billion in 2018 (7.7 billion in the U.S. alone) this corporation has an important and influential impact on consumer dining habits (Statista 2018).

Previous research investigating eating habits across different age groups found that people eighteen to twenty-four years of age are the most likely to consume fast food (Anderson et al. 2011). Additional research supports this finding, with 52 percent of individuals twenty to thirty-nine years old reportedly consuming fast food more frequently than any other age group (McDonald's 2016, Paeratakul et al. 2003, Vikraman et al. 2015). These repeated, frequent, acute exposures to fast-food meals may lead to a premature stiffening of the arteries in a young cohort of subjects. Therefore, the purpose of my study was to determine whether ingestion of a typical fast-food meal acutely changes aortic stiffening. I, along with the help of my faculty mentor, Dr. Timothy J. Quinn, hypothesized that postprandial (postmeal) increases in aortic arterial stiffness would be observed after the consumption of a fast-food meal high in fat, sodium, and cholesterol, in a subject group consisting of individuals between the ages of eighteen and thirty.

How the Arteries React to Consumption of a Fast-Food Meal

Arterial stiffness is defined as the general inability of arteries to vasodilate (expand to increase artery diameter) and vasoconstrict (contract to move blood through the arteries) to accommodate changes in blood flow and pressure. While being a health concern itself, arterial stiffness also is an indicator of more serious cardiovascular complications such as stroke, heart attack, high blood pressure, and congestive heart failure (Berry-Miller. 2007, Berry-Tucker. 2008, Herrington et al. 2004, Laurent et al. 2006, Mitchell et al. 2010).

The major artery that we are concerned with when measuring arterial stiffness is the aorta. Because the aorta is in the chest cavity directly above the heart, we can't measure its stiffness using a traditional cuff and scope. Aortic, or central stiffness, is assessed with applanation tonometry, a method that measures the speed of pressure waves being generated when the heart beats.

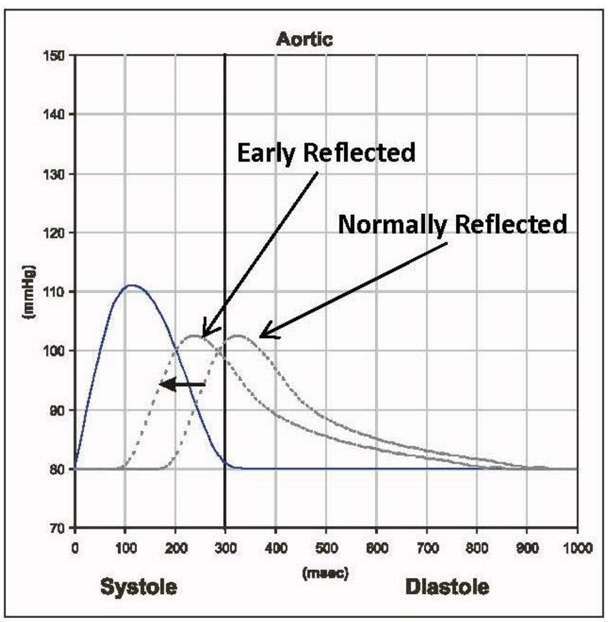

Figure 1. Example of early and normal returning pressure waves, which represent stiff vs compliant arteries respectively, captured using applanation tonometry. Blood pressure on the Y axis is measured in millimeters of mercury, and time on the X axis is measured in milliseconds.

With each beat of the heart, a pressure wave travels through the arteries and veins to the farthest and smallest capillaries within the body. As the pressure wave hits the many bifurcations of the arterial system, where vessels branch out into two or more smaller vessels, small reflected waves are generated, eventually summating into one large reflected pressure wave that travels back toward the heart (Sugawara et al. 2005). The time that the reflected wave takes to reach the heart gives an idea of the stiffness of the arteries. More elastic arteries display a longer time for the reflected wave to reach the heart (Figure 1). Stiffer and less elastic arteries display a faster reflected pressure wave, which indicates that more strain is being placed on the heart to pump blood.

Complications of stiffer arteries include an increase in central systolic blood pressure, or the pressure during contraction and subsequent ejection of blood from the heart, and in central pulse pressure. Pulse pressure is determined by the difference between the central systolic blood pressure and the diastolic blood pressure, which is the pressure in the arteries during relaxation of the heart when it is being refilled with blood. As such, measurements of pulse pressure are indicative of cardiac output, or the volume of blood ejected from the left ventricle per minute. With stiffer arteries, the heart needs to generate more pressure, which causes its left ventricular wall to increase in size to meet that need. Over time, this reduces the chamber size of the left ventricle and reduces the volume of blood the left ventricle is able to hold and then eject, reducing the cardiac output.

Chronic arterial stiffening occurs passively as we age, and no conclusive evidence about how to attenuate this has been found (Greenwald 2007). However, previous research suggests that acute arterial stiffening occurs in otherwise healthy individuals when in a postmeal state following the consumption of a meal high in fat, salt, and cholesterol, such as a typical fast-food meal (Edmondson 1975, Oberleithner 2007, Todd 2010).

Figure 2 shows nutritional information for the Big Mac meal, a popular fast-food menu item that I chose for my experiment. The amount of sodium (1,180 mg) it contains is nearly half the recommended daily value. Research has found that sodium greatly affects both arterial stiffness and stress, or the extent of pressure and stretching the arteries must withstand to accommodate blood flow changes (Gates et al. 2004, Safar et al. 2009).

Calories	870	-
Calories from fat	400	-
Total Fat	44 g	68% DV
- **Saturated fat**	12 g	60% DV
- **Trans fat**	1 g	-
Total Carbohydrates	90 g	30% DV
Protein	29 g	-
Cholesterol	80 mg	26% DV
Sodium	1180 mg	49% DV
Dietary Fiber	7 g	29% DV
Sugars	9 g	-
Vitamin A	510 IU*	10% DV
Vitamin C	13 mg	20% DV
Calcium	160 mg	15% DV
Iron	5.5 mg	30% DV

Figure 2. Nutrition facts of a popular fast food meal (Big Mac hamburger and medium french fry) with percentage of daily value (DV) included.

The large amount of sodium ingested causes stiffening of the arterial wall by limiting the amount of regulating hormones able to be released by the surrounding arterial tissue. Sodium also causes increases in blood volume, because more water is needed to dilute the sodium in the bloodstream. With increased blood volume, more blood must be pumped per heartbeat and more blood is pushing on the inner walls of the arteries. This can result in increased systolic blood pressure and diastolic blood pressure. The stress of increased blood volume and higher systolic and diastolic blood pressures reduces the arteries' ability to contract and relax.

The initial increase in diastolic blood pressure that may result from ingesting a large amount of sodium is a compensatory mechanism to increase blood flow to the coronary arteries, which are the arteries that supply oxygenated blood to the heart. A significant complication arising from increased arterial stiffness is a decrease in the flow of blood to the coronary arteries. The pressure of an early returning wave, which results from increased arterial stiffness, lessens the flow of blood to these arteries. This can lead to an increased risk of both myocardial ischemia (lack of blood flow to the heart muscle) and/or heart attack (death of heart muscle tissue).

Equipment and Subject Recruitment

Applanation tonometry is the hallmark noninvasive method for determining arterial stiffening, which is why I chose to use it for my research. It measures arterial stiffness via pulse wave analysis. A device called a tonometer is placed on the wrist and records the radial (wrist) artery pressure waveform. A formula called the aortic augmentation index (AIx) determines central arterial stiffness based on the tonometer's measure of the pressure wave in the radial artery. I was shown how to use the applanation tonometry equipment in the kinesiology lab at the end of my junior year so that I would be well versed in how to operate the equipment for my research.

Applanation tonometer device being placed over the radial artery on the right wrist to aquire central measures of arterial stiffness. *Photo by Emily Morenz.*

Before any actual participants were brought in, I performed preliminary pilot testing to fine-tune the smaller nuances of the study, such as how much water each participant was allowed to have and the time limit within which they were asked to finish their meal. During the pilot testing I also became curious about when exactly the effect of the fast-food meal was most prevalent, therefore leading to the greatest change in arterial stiffness. I determined that to collect as much data as possible and therefore gauge when the most significant changes occurred, twenty-minute intervals would be the most efficient.

Through fliers, social media posts, and emails, I recruited ten participants, who individually reported to the Robert Kertzer Exercise Physiology Laboratory at UNH and completed a health history questionnaire and an informed-consent form. I then assessed each subject's height, weight, and blood pressure. After this, I asked the participants to eat and finish the meal, a Big Mac hamburger and a medium order of french fries, within a twenty-minute time frame. All participants consumed the meal at the laboratory, where I could monitor the time for consistency. After each participant finished the meal, I remeasured blood pressure, using an automated blood pressure cuff, and arterial stiffness, via applanation tonometry, every twenty minutes for two hours.

I analyzed and interpreted the data collected from the ten subjects with SPSS statistical software (Version 23). Premeal measurements were compared with postmeal measurements to determine if significant changes occurred.

Findings from the Arterial Stiffness Measurements

Postmeal measurements of systolic blood pressure, pulse pressure, heart rate, and aortic augmentation index all proved not to be significantly different from the premeal measurements. This was surprising to me, given that systolic blood pressure is known to be higher when large amounts of sodium are ingested, such as in the fast-food meal. Additionally, I had thought that heart rate would increase because of the body retaining water to dilute the excess sodium within the bloodstream. I also expected the values for pulse pressure following consumption of the meal to show more of a significant change from the pre-meal measurements because of the acute arterial stiffness that I hypothesized to occur. Similarly I hypothesized that aortic augmentation index would increase as the arteries stiffened. The results, however, did not illustrate these effects.

In contrast, central diastolic blood pressure did show a significant change postmeal (Figure 3). It decreased for a period of time after the ingestion of the fast food, which indicates that the blood pressure during the relaxation phase of the heartbeat was lower than normal. The greatest decrease in central diastolic blood pressure was found to be at the forty to sixty-minute mark following the consumption.

As mentioned previously, an acute elevation in central diastolic pressure is the primary mechanism that drives blood into the coronary arteries. The drop in diastolic blood pressure that I witnessed suggests that the coronary arteries were not being adequately supplied with oxygen-rich blood after the ingestion of a quick service meal. It's possible to detect this only through the use of applanation tonometry equipment, because peripheral changes take longer to appear than central measures. I was surprised to see that a significant decrease occurred rather than an increase and that the exact mechanisms of this decrease are unknown.

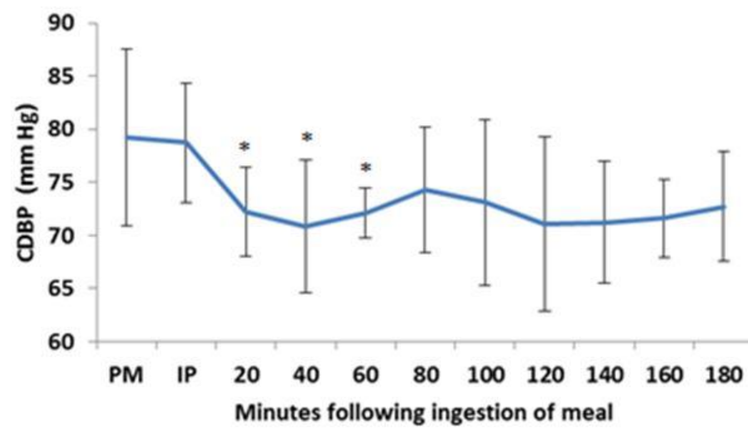

Figure 3. This figure shows the significant decrease in central diastolic blood pressure (CDBP) using the means for all participants that I observed following the ingestion of the fast food meal. The significant decreases are identified by the asterisk above the 20, 40, and 60 minute marks.

My theory is that the salt, carbohydrates, and sugars in the meal caused the decrease in diastolic blood pressure. The fats and proteins take more time to digest, and it is therefore doubtful that they could affect arterial stiffness within the time window of my measurements. The combination of salt, carbohydrates, and sugar could have caused a decrease in naturally produced nitric oxide within the arteries. The exact mechanisms of how salt, sugar, and carbohydrates impair nitric oxide production are still unclear, but nitric oxide is important in regulating the relaxation (opening) of the arteries, which allows greater amounts of blood to flow. The decrease in nitric oxide production could have acutely impaired the ability of the arteries to relax, therefore causing stiffer arteries. This would cause the heart to work harder to push the blood through the arteries, and the coronary arteries would have a harder time supplying the heart itself with oxygenated blood. I believe that the decreased diastolic blood pressure I observed reflected this reduction in blood flow to the heart via the coronary arteries.

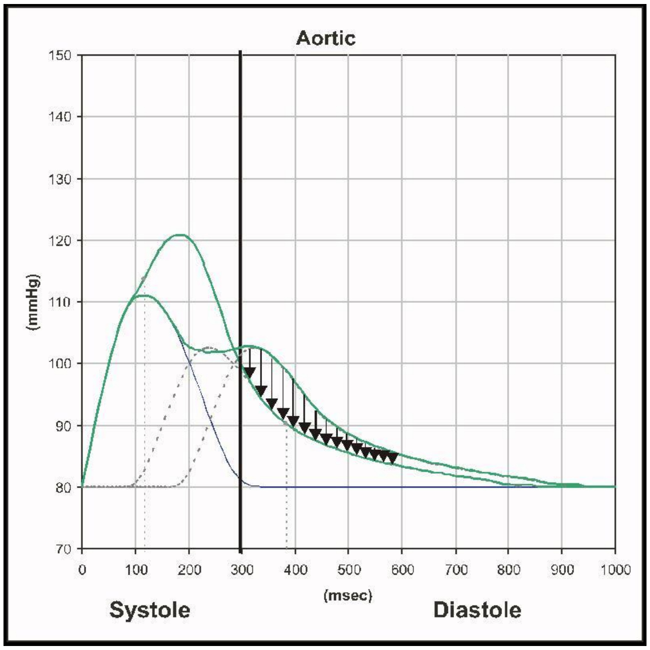

Figure 4. Example of decreased coronary artery perfusion (indicated by the downward arrows) due to lower diastolic pressure caused by increased arterial stiffness. Blood pressure on the Y axis is measured in millimeters of mercury, and time on the X axis is measured in milliseconds. Measurements were taken using applanation tonometry. This is an example of what happens to an individual with stiffer arteries and does not represent any values obtained during my testing.

This can be seen in Figure 4. The coronary arteries, unlike all other arteries, are filled with blood during diastole. With decreased diastolic blood pressure, the coronary arteries receive a decreased amount of blood and therefore are not doing the best job they can to supply the heart with oxygenated blood. This situation is dangerous, especially if repeated with frequent visits to fast-food locations, and can potentially lead to heart muscle death if the tissue is not receiving enough oxygenated blood.

The findings of my study showed that although only one measure of arterial stiffening was found to be significantly different (diastolic blood pressure), the consumption of a fast-food meal does acutely affect arterial stiffness. Although diastolic blood pressure alone is not an indication of arterial stiffness, it does give insight into the level of blood flow that the heart muscle is getting, which in turn could be affected by an increase in arterial stiffness. However, more conclusive evidence is needed to support this theory.

The probability is high that more significantly different results of before- and after-meal consumption would be observed if there was a larger cohort of subjects for the study. The study group was only half the desired size. I am working to recruit all twenty participants and am confident that with more trials the results will show more significance.

Conclusion

Conducting undergraduate research allowed me to work independently under the guidance of a faculty mentor, and to develop a working research protocol to acquire the necessary data. I had never been involved in research in the past, but I knew that I wanted to pursue a Summer Undergraduate Research Fellowship because of this lack of experience. This research allowed me to leave my comfort zone and enter an area of science that I had never been exposed to before. It is both satisfying and exciting to venture into new areas and feel that you are contributing to that field of knowledge, whether or not your hypothesis is proven correct.

After graduating from UNH in 2019, I will begin a ten-week summer internship, after which I plan on working for and learning from both strength and conditioning coaches as well as physical therapists to broaden my view of exercise as a science and to see the extent of what exercise physiologists have done for this field. I would also love to return to research one day.

My goal in publishing this article is to increase awareness of the health consequences caused by chronic consumption of fast food, the mechanisms that contribute to arterial stiffening, and the potential for arterial damage. I would like readers to think about how to improve the nutritional balance of what they eat on a day-to-day basis. My hope is that the findings of this study will be a reminder to some, especially younger individuals, that even if they cannot see the harmful effects of fast food, it is occurring regardless and can build upon itself over time, leading to problems later in life.

I would like to thank my mentor, Dr. Timothy J. Quinn, for his motivation to become involved with research and for his consistent help throughout the process of writing the proposal for the SURF grant. I would also like to thank the Hamel Center for Undergraduate Research and Mr. Dana Hamel for the funding to make this research possible. Thank you to Mr. Peter Akerman, who was extremely helpful and accommodating to the parameters of this research, and thank you to the subjects, who volunteered their time to make this research possible. To all of my peers who also completed research this summer, thank you for the continuous support and assistance as well as for inspiring me to constantly seek out new opportunities and go outside my comfort zone.

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Author and Mentor Bios

Erik J. Harrington, from Deerfield, New Hampshire, will graduate from the University of New Hampshire (UNH) in 2019 with a degree in kinesiology: exercise science. Through his project, which was funded by a Summer Undergraduate Research Fellowship, he learned about “some of the many factors that contribute to the health and the degradation of the cardiovascular system as well as how to monitor and measure all of the variables that go along with this system.” His research experience was an important achievement for Erik, who gained skills in recruiting subjects, analyzing data, and operating sophisticated laboratory equipment. He also thoroughly enjoyed the relationships he built with his participants and peers. Erik looks forward to one day opening his own facility incorporating strengthening and conditioning as well as aspects of physical therapy.

Timothy J. Quinn is an associate professor in the University of New Hampshire (UNH) Department of Kinesiology. He began working at UNH in 1989 and specializes in researching cardiovascular physiology in addition to teaching a variety of kinesiology courses. He mentored Erik through research that first arose from a blood flow experiment in one of Dr. Quinn's classes, in which they were able to show how sluggish blood flow became after the ingestion of a fast-food hamburger. Of mentoring, Dr. Quinn said, "It is always a joy to see a student learn new things in the laboratory that just cannot be taught in a classroom to a large group of students." He enjoyed watching Erik develop the applanation tonometry measurement technique used in his study and was impressed with the time and effort Erik was willing to put in to truly master the technique. Dr. Quinn believes that there are many more avenues to research related to changes that occur in the body after fast-food meals. He has mentored many undergraduate researchers in the past; perhaps some of his future mentees will continue to address some of the important questions related to the effects of fast food on the cardiovascular system.