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The Correlation Between Heart Rate Variability and Diet

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Abstract

Heart function can be affected by lifestyle choices. Heart rate variability (HRV) is a physiological phenomenon that accounts for the variation in the time interval between heartbeats and can be used as a means to assess cardiac health[14]. A high HRV is indicative of good cardiac health and increased parasympathetic activity, while a low HRV has been associated with poor cardiac outcomes in adults[7]. This study investigated the correlation between overall diet and HRV. Thirty-two participants aged 18-22 years old were recruited based on diet. Diets included vegetarian and gluten-free, as well as participants with no dietary restrictions. A 5-minute electrocardiogram (ECG) was performed on each participant. Software supplied by ADInstruments was used to generate a spectral analysis of HRV by applying a Fast Fourier Transformation (FFT). Frequencies were subdivided as Very Low Frequency (VLF) and Low Frequency (LF), which correlates to a combination of sympathetic and parasympathetic effects, and High Frequency (HF), which correlates to parasympathetic effects. Time domain and frequency domain measures of HRV were analyzed through SPSS. No significant differences between the diet groups were found; however, there were differences in the standard deviation of all normal RR intervals (SDRR) of each group (vegetarian = 104.66 ms, gluten-free = 81.5 ms, healthy = 66.34 ms, unhealthy = 59.13 ms, and control = 87.07 ms). A moderate negative correlation was found between consumption of fast food and frequency HRV measures (HF power: $r = -.397$, $p = .024$), indicating that with increasing fast food consumption, there is an increasing risk for adverse cardiac outcomes. In general, diet does seem to result in small differences in HRV, especially between the unhealthy diet group and the vegetarian diet group, specifically for the LF domain ($p = 0.17$). Additionally, after sorting the data through time domains, it was found that the vegetarian group had an SDRR value greater than 100 ms, correlating with a low risk of cardiac problems as determined by previous parameters[17].

Keywords: Heart Rate Variability, Diet, Autonomic Balance

1. Introduction

Heart rate variability (HRV) is a physiological phenomenon that accounts for the variation in the time interval between heartbeats. HRV is affected by both the parasympathetic and sympathetic divisions of the autonomic nervous system. The HRV of an individual can be used to assess the overall health of the heart and HRV can provide information of how different factors may be related to cardiac health[14]. Increased variability reflects increased parasympathetic control of the heart rate and good cardiac health[14].

HRV can be used to assess cardiac health and has been found to have a predictive value for mortality among adults. Kristal-Boneh et al. published evidence that, following a myocardial infarction, patients with a low HRV had a five times higher risk of death than patients with a high HRV[7]. Low HRV has been correlated with the occurrence of many forms of cardiovascular diseases, including coronary artery disease, congestive heart failure, and ischemic heart disease[7].

Other research has examined the correlation between different lifestyle factors and HRV. Previous studies have found that there is a relationship between increasing age and decreasing HRV[11]. Individuals who exercise regularly have an increased HRV and older adults that have been put on an exercise regime have been able to increase their HRV[15]. More recent studies have found that smoking, whether chronic or acute, can result in a reduced HRV and in addition, nonsmokers who experience secondhand smoke, whether chronic or acute, also have a reduced a HRV[2]. Diabetes is also known to be a major risk factor for cardiovascular disease[13] and Liao et al. has shown that individuals with diabetes were found to have a decreased HRV compared to those without diabetes[8]. These research studies show that activities that are generally considered beneficial to heart health, such as exercise, subsequently result in a higher HRV. Risk factors for heart disease, such as smoking and diabetes, are found to result in a lower HRV.

Often it can be difficult to assess if certain lifestyle factors are detrimental or beneficial to cardiac health. The best way to investigate this would be through a longitudinal study to observe whether individuals with potential risk factors develop a form of heart disease in their lifetime. However, this is not the most feasible option because it is time-consuming and costly. HRV provides a solution to this problem because it can be used as an effective measure for assessing overall cardiac health.

Diet is one lifestyle factor that can either help or hurt cardiac function, depending on the types of foods consumed by the individual. A higher intake of fish, vegetables, and fruit generally leads to beneficial changes in HRV[10]. In addition, there is a significant association between high cholesterol and low HRV[3]. This is important to note because a high level of LDL cholesterol in the body is also a main risk factor for heart disease. Therefore, HRV can be used as a method to provide insight into how nutrition and diet play a role in cardiac health. Specific aspects of diets have also been previously examined using HRV. In order to investigate the relationship of sodium to HRV, researchers placed individuals on a low sodium diet for a week and then subsequently switched these individuals to a high sodium diet for an additional week. After increasing sodium intake, individuals had a lower HRV than when they had been placed on a low sodium diet[9]. Individuals with high levels of alcohol use have been found to have a lower HRV than peers who do not consume alcohol[18].

Although specific aspects of diet have been correlated to HRV, there is a lack of research in the literature about how overall diet impacts HRV. Certain diets have been linked to an increased risk for developing heart disease. The typical Western diet of high salt and red meat consumption, refined vegetable oils and sugars, cereals, and dairy has been associated with an increase in prevalence of chronic disease among the populations of Western countries[4]. Another study found that a higher consumption of red meat, processed meat, refined grains, and high-fat dairy (typical aspects of a Western diet) led to an increased risk for coronary heart disease[5]. Cardiovascular risk factors have been found to change significantly in celiac patients that had adopted a gluten-free diet. However, the changes were not all positive or negative, as cholesterol levels increased but homocysteine levels decreased in these participants[19]. On the other hand, individuals who adhere to a vegetarian lifestyle were found to be at a decreased risk for developing cardiovascular disease[12]. These previous studies show that perhaps it is not just a specific aspect of diet than can lead to health issues, but rather the overall diet. This merits further study into the impact of diet on cardiac health as measured through HRV.

We hypothesize that individuals who adhere to a vegetarian diet will have a higher HRV compared to other diet groups and therefore, have a better long-term cardiac prognosis. Additionally, we hypothesize that individuals who follow a "Western" diet, characterized by high fast food, red meat, sugar, and dairy consumption will have more negative outcomes in terms of HRV. Finally, we hypothesize that other diet groups will fall between this range but we cannot hypothesize exactly how they will impact an individual's HRV due to the lack of research with these specific diets.

2. Methods and Materials

2.1. Participants

Participants were college students aged 18 to 22 years old who attended Elon University. Of the 32 participants recruited in total, 26 were female and 6 were male. All of the participants involved in this study gave informed consent.

2.2. Procedure

Each participant was assigned a number prior to data collection so as to keep their results confidential. This study tested each participant around the same time each day, between the hours of 8:00 am to 12:00 pm as HRV can be influenced by circadian rhythm[14]. Participants were then given a survey detailing their day-to-day eating habits including specific dietary restrictions. If the participant indicated any specific dietary restrictions, this was used to categorize the participant into a diet group.

The diet groups consisted of vegetarian, gluten-free, unhealthy, healthy, and moderate. There were 9 individuals in the vegetarian group, 3 in the gluten-free group, 4 in the unhealthy group, 5 in the healthy group and 11 in the moderate group. The vegetarian group consisted of participants who abstained from eating meat. This included red meat, chicken, and fish. The gluten-free group consisted of individuals who did not eat gluten. The unhealthy group was characterized by a high consumption of fast food, sweets, red meat, and alcohol and a low consumption of fruits and vegetables. Consumption was determined based on the frequency that individuals consumed certain foods. A high consumption rate was determined to be at least once a day. A low consumption rate was determined to be a few times a year. The healthy group was characterized by a low consumption of fast food, sweets, red meat, and alcohol and a high consumption of fruits and vegetables. The moderate group was defined as consuming a low amount of red meat and fast food, while also consuming a moderate amount of grains, vegetables, fruit, fish, and chicken. A moderate consumption was determined to be a few times a week or less. The moderate group functioned as a control group. Gender, race, height, and weight of each participant were self-reported in the survey in order to account for BMI. The survey also inquired about other lifestyle choices that had the potential to act as confounding variables during data analysis, such as smoking, alcohol use, exercise, and caffeine intake.

Following the survey, the participants were connected to standard lead I ECG setup that was connected to a bioamplifier (ADInstruments, Colorado Springs, CO), and analyzed on a MAC computer. An ECG of five minutes was run while the participant sat in a relaxed fashion. The data was saved to both the computer and a flash drive.

After completing data collection in the lab, the data was statistically analyzed using SPSS. The data was examined using both the time and frequency domain measures of HRV[6].

2.3. Analysis

HRV measures can be expressed in a number of ways[6]. The following parameters were defined for the time domain: the average RR intervals, median RR interval, the standard deviation of RR intervals (SDRR), root mean square of successive differences (RMSSD), and the percentage of differences higher than 50 milliseconds in RR intervals (pRR50). Table 1 shows reference values for the statistical parameters for time domain measures including risk level stratification[17].

A spectral analysis of the HRV data for each participant was generated by applying a Fast Fourier Transformation (FTT) to the raw data using ADInstruments software[17]. With concern for the frequency domain, the following frequency divisions were defined: high frequency (HF) from 0.15 to 0.4 Hz; low frequency (LF) from 0.04 to 0.15 Hz; and very low frequency (VLF) from 0.03 to 0.04 Hz[17].

Descriptive statistics of demographic information and HRV were obtained. An ANOVA was run to compare the time domains and frequency domains of HRV between the different diet groups to determine whether there were significant differences between the groups. Subsequent independent samples t-tests were run in order to further elucidate possible significant differences between specific diet groups. Finally, a Pearson correlation was run against the frequency of consumption of specific foods and the various time and frequency domains of HRV.

Table 1. References for the statistical parameters in the time domain, including the risk level stratification[17]

Averaged RR interval	RR < 750 ms → high
	RR 750-900 ms → moderate
	RR > 900 ms → low
SDRR	SDRR < 50 ms →high
	SDRR 50-100 ms → moderate
	SDRR > 100 ms → low
pRR50	pRR50 < 3% → high
	pRR50 ≧ 3% → low
SDARR	SDARR < 8 ms → high
	SDARR 8-12 ms → moderate
	SDARR ≧12 ms → low
SDRR index	SDRR index <25 ms
	SDRR index = 24-40 ms
	SDRR index ≧ 40 ms
SDRR, standard deviation of RR intervals; pRR50, percentage of differences higher than 50 ms in RR intervals; SDARR, standard deviation of averaged RR intervals over 5 minute periods.	

3. Results

Descriptive statistics were calculated in SPSS in order to find the means and standard deviations of the different diet groups in the time and frequency domains of HRV. Tables 2a and 2b show the descriptive statistics for the five diet groups. The differences in the SDRR values of the various groups are important to note. The mean SDRR of the vegetarian group was 104.7 ms, the control group was 87.1 ms, the gluten-free group was 81.5 ms, the healthy group was 66.3 ms, and the unhealthy group was 59.1 ms.

Table 2a**.** Descriptive statistics of diet groups with time and frequency domains of HRV

	Vegetarian		Gluten-free	
	Mean	SD	Mean	SD
Average RR (ms)	850.8	107.8	855.5	127.4
Median RR (ms)	840.3	115.6	856.7	134.1
SDRR (ms)	104.7	80.1	81.5	22.1
RMSSD (ms)	99.6	107.5	78.5	34.1
HR (bpm)	72.7	10.5	71.8	1.9
VLF power (ms^2)	4438.4	6879.3	1527.4	1143.3
LF power (ms^2)	6091.7	6899.4	2666.7	1289.8
HF power (ms^2)	13058.3	25013.5	3399.4	3567.4
LF/HF	1.9	2.0	1.9	2.33
SD, standard deviation; HR, heart rate				

Table 2b**.** Descriptive statistics of diet groups with time and frequency domains of HRV

	Healthy		Unhealthy		Control	
	Mean	SD	Mean	SD	Mean	SD
Average RR (ms)	854.7	137.8	801.3	73.9	830.9	88.2
Median RR (ms)	852.7	144.4	795.7	71.1	824.2	85.6
SDRR (ms)	66.3	30.0	59.1	8.23	87.1	34.2
RMSSD (ms)	47.4	18.5	45.5	10.8	95.4	52.3
HR (bpm)	72.0	11.9	75.7	6.7	73.8	8.6
VLF power (ms^2)	9051.4	14297.7	849.8	102.3	2244.8	1570.2
LF power (ms^2)	24373	37891.5	1646.3	941.6	3603.5	1956.8
HF power (ms^2)	43900.7	72747.4	940.6	655.9	5960.7	4095.7
LF/HF	1.02	0.47	2.05	0.88	1.0	1.3
SD, standard deviation; HR, heart rate						

Using the values from Table 1 as a reference, participants with an SDRR value of over 100 ms are categorized into the low risk stratification for negative cardiac outcomes. The only diet group to have a mean SDRR value of over 100 ms was the vegetarian group. The unhealthy diet group had the lowest mean SDRR value, consisting of 59.1 ms. Analysis of the data obtained very high values for standard deviations when descriptive statistics were calculated, showing that there is a lot of variability within the data.

A one-way Analysis of Variance (ANOVA) was conducted to compare the frequency domains of HRV (VLF power, LF power, and HF power) for participants of different diet groups. There was no significant difference in the diet groups for the frequency domains of HRV. A one-way Analysis of Variance was conducted to compare the time domains of HRV (SDRR, RMSSD, and pRR50). There was no significant difference in the diet groups for the time domains of HRV.

Further statistical analyses were run in order to elucidate small differences between specific diet groups. Since the largest difference in SDRR value was between the vegetarian and the unhealthy diet groups, an independent samples t-test was conducted through SPSS on these two groups. There was no significant difference in the SDRR between the vegetarian and the unhealthy diet group; $t = 1.014$, $p = .327$. Additional time domain measures were also tested for the independent samples t-test. There was no significant difference in the RMSSD between the vegetarian and the unhealthy diet group; $t = .580$, $p = .571$. There was no significant difference in the pRR50 between the vegetarian and the unhealthy diet group; $t = -.109$, $p = .915$.

Frequency domains were tested in the independent samples t-test between the unhealthy and vegetarian diet groups. There was no significant difference in the VLF power between the vegetarian and the unhealthy diet group; $t = 1.193$, $p = .252$. There was no significant difference in the LF power between the vegetarian and the unhealthy diet group; $t = 1.454$, $p = .17$. There was no significant difference in the HF power between the vegetarian and the unhealthy diet group; $t = 1.060$, $p = .306$. These results show that there were no statistically significant differences in either the time domains or the frequency domains for HRV between the vegetarian and the unhealthy diet groups.

One aspect of the survey asked participants to indicate how often they consumed different types of food on a weekly basis: fast food, dark green leafy vegetables, grains, fruits, red meat, chicken, fish, eggs, beans, nuts, tofu, dairy, and sweets. All of these specific aspects of diet were analyzed in SPSS with a Pearson correlation to investigate whether any of them were significantly correlated with the time or frequency domain measures of HRV.

A significant correlation was found between consumption of fast food and several of the HRV domains as depicted in Table 3; however, no similar significant correlation was found with the other aspects of diet. A Pearson correlation coefficient was calculated to examine the relationship between fast food consumption and the various HRV time and frequency domains. When using the pRR50 time domain measure, a weak negative relationship was found, $r = -.163$, $p = .05$. The frequency domain measures were shown to have moderate negative correlations to the consumption of fast food. For the VLF power, a significant correlation was found, $r = -.393$, $p = 0.026$. For the LF power, a significant correlation was found, $r = -.377$, $p = .033$. Finally, for the HF power, a significant correlation was found $r = -.397$, $p = .024$. These results indicate that fast food is correlated with lower HRV domains in the participants of the study.

Table 3. Pearson correlation statistical analyses of consumption of fast food versus time and frequency HRV domains

			Average RR	Median RR	pRR50	VLF power	LF power	HF power
Fast food	Pearson Correlation	R value	-.450	-.431	-.350	-.393	-.377	-.397
	Sig. (2-tailed)	P value	.010	.014	.050	.026	.033	.024
	N		32	32	32	32	32	32

4. Discussion

The purpose of this research study was to determine whether specific diets could be correlated with differences in HRV. It has been established that specific types of food can lead to a better or worse prognosis for future cardiac health[3,10] but this study was novel in that it looked at how the overall, more restrictive diets impacted HRV. With the rise of vegetarian and gluten-free diets, it is interesting to see whether the transition to a new diet may be related to changes in cardiac health, as measured through HRV.

As stated previously, higher values for the different domains of HRV are associated with beneficial cardiac outcomes, while lower values are associated with adverse cardiac outcomes[7,14,17]. In addition, previous research has already provided references for the statistical parameters in the time domain and has included the risk stratification for these parameters[17]. In particular, examining the mean SDRR of the different diet groups proved to be insightful. This study found that the diet groups ranked in the following order from highest to lowest SDRR: vegetarian, control, gluten-free, healthy, and unhealthy diets. In addition, the vegetarian group was the only diet group to be categorized into the low risk stratification for future adverse cardiac outcomes. While others were categorized into the moderate risk stratification, the unhealthy diet trended towards high risk, due to having a lower SDRR value. In terms of the SDRR time domain measure, the vegetarian diet group had the most favorable HRV and potentially, the lowest risk for negative cardiac outcomes in the future. The unhealthy diet group had the lowest value for SDRR and therefore, the eating habits of this group may lead to future heart conditions.

However, further statistical analyses revealed that there was no significant difference between the diet groups for both the different time and frequency domains that were tested. Therefore, although the mean SDRR revealed interesting results that may indicate the effects of diet on HRV and cardiac health, it cannot be conclusively determined that different diets have a direct relationship to changes in cardiac health.

Another attempt to elucidate differences between the diet groups was made through an independent samples t-test. This was specifically run between the vegetarian and the unhealthy diet groups because these groups had the largest difference in mean SDRR. However, no significant differences between the time and frequency domains of HRV were found between the unhealthy group and the vegetarian group. The p-value for the difference in LF power between the vegetarian and unhealthy diet groups did lean towards significance ($p = 0.17$). Perhaps by recruiting more participants in each diet group and more participants for the study overall, HRV differences may result in being significant.

The findings from the Pearson correlation showed that increased fast food consumption is negatively correlated with HRV ($p \leq 0.05$). This correlation was the only statistically significant result in the study. These results indicate that with increasing fast food consumption, there is an increasing risk for an adverse cardiac prognosis.

This study focused on college students, a population that is perceived to have more unhealthy behaviors than the average population. In fact, in a recent study documenting the prevalence of fast food consumption among college students, an overwhelming 87% reported that they had consumed fast food recently, and two-thirds of the respondents reported that they eat fast food multiple times per week[16]. The unnatural hydrogenated *cis* and *trans* unsaturated fatty acids found in a majority of fast food options are expected to have contributed to the increase in heart disease over the past few decades and are consequently seen as a major risk factor of the disease[1]. Overall, the results from this study, in particular the Pearson correlation analysis, support the assertion that higher consumption of fast food can lead to negative measures of HRV. The results are also relevant to broader public health implications. They indicate that college students may be a population that should be targeted in campaigns about the necessity of eating healthy and nutritious foods, such as consuming more fruits, vegetables, and lean meat on a weekly basis, as opposed to turning to fast food.

There are several limitations of this study that must be noted and taken into consideration. One limitation of this study was the method by which participants were categorized into diet groups. Participants reported on the survey whether they had any existing dietary restrictions and therefore, this resulted in the categorization being subjective. For example, there are many variations of vegetarians depending on the specific individual. Some vegetarians will eat fish while some will abstain from all meat, including eggs. In addition, some individuals may classify themselves as vegetarians, but may still consume meat on a regular, if not frequent, basis. Therefore, the use of surveys is a somewhat subjective measure of assessing different variables. Another limitation of this study was the possibility of confounding variables. Although the survey given to participants attempted to take various confounding variables, such as caffeine intake, smoking and alcohol use, and exercise, into consideration, there are a variety of other factors, ranging from environmental to genetics to lifestyle factors, which can each have a substantial effect on HRV and cardiac health. Some of these variables may not have been taken into account when conducting the data analysis.

Future research into HRV and diet may help elucidate the health benefits or detrimental effects of the many diets that are rising in popularity in the United States. There are also other diets that were not assessed in this research project. Assessing other diets, such as dairy-free diets, vegan diets, and Paleo diets may provide more insight into how adopting these diets impact HRV. Overall, it is essential to investigate whether each diet may have a potential beneficial or adverse relationship with cardiac health, as measured through differences in HRV.

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