An Analysis of Abnormal Electrocardiograms in First and Second Year Medical School Students

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AN ANALYSIS OF ABNORMAL ELECTROCARDIOGRAMS IN FIRST AND SECOND YEAR MEDICAL SCHOOL STUDENTS

A Thesis in Biomedical Sciences by Molly Anne Kalish

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Submitted in Partial Fulfillment of the Requirements for the Degree of Masters of Science in Biomedical Sciences
June 2014
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Abstract

The high stress level placed upon medical school students, particularly during their first and second didactic years, may have a negative effect on their health. Although surveys and subjective questionnaires have been used to evaluate the effects medical school has upon a student’s cardiovascular health, there has been little clinical data obtained to confirm this notion. The aim of this longitudinal study was to demonstrate whether any abnormal cardiovascular parameters, specifically QTc wave interval, cardiac axis vector and blood pressure abnormalities, could be documented to occur in two different classes of medical students during their first two years. Such information can hopefully shed more light on this under investigated area of cardiology and produce more effective prevention and awareness among these young adults.

Blood pressure and electrocardiogram recordings obtained from members of the graduating class of 2012 and 2013 at the Philadelphia College of Osteopathic Medicine were analyzed to determine the number of abnormalities present as well as to compare the difference in frequencies of these abnormalities in male and female medical students. Blood pressure data revealed a statistically significant difference in the frequency of abnormally high blood pressure readings in male compared to female medical students for each class year analyzed. QTc interval data and cardiac axis vector data revealed no statistically significant differences between the sexes during each academic year. Analysis was confounded by the lack of guidelines for young adults in the cardiovascular literature.

This lack of information concerning the cardiovascular health of young adults and in particular medical students is one of the main reasons why such data analysis is crucial and must be continued. Further research and analysis are essential to this underdeveloped area of
cardiology and is a primary rationale for this study and crucial to increase the awareness of cardiovascular predispositions, risk and abnormalities in this population of future healthcare providers.
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Chapter 1

Introduction

The medical school curriculum presents students with a demanding task that requires an intense commitment to their studies combined with many lifestyle challenges. Responsibilities and workload can infringe upon these students’ daily life activities and become a source of heightened stress. Studies that examine aspects of medical students’ lives encompass a broad range of areas that contribute to the overall health and well-being of the student. However, there is limited objective data regarding their cardiovascular health during medical school despite the fact “that personal health experiences of medical school students have implications for their future patient care, practices, and attitudes” (1). Stress is a major contributor to many health problems, including those related to cardiovascular health. Another study of medical students perceived stress (PMSS) reported considerable variability in PMSS among medical students with 50% reporting high PMSS in September. These data support the notion that early on medical school is indeed perceived to be stressful by a significant number of students” (2). Another study revealed evidence of an adverse relationship between academic study and cardiovascular health among medical students. One result of this study was that the students’ high-density lipoprotein cholesterol (HDL-C) levels and total HDL-C/total cholesterol ratios, changed unfavorably in relation to their final examination schedules. This factor may contribute to a greater risk for developing coronary artery disease in these individuals (3).
A study conducted at Johns Hopkins School of Medicine found that students’ cholesterol levels increase during exam preparation, particularly during the first few months of medical school when the students are still adjusting to their new environment (4). An interconnection also has been found between medical students’ motivation, school grades, depression and personality (5). It appears that depression and personality changes can and do occur in medical students, and these changes are often associated with the stress of exam performance. This article further stated that, “these findings suggest that the early years of medical school are the most stressful and that the ideal time for interventions might be at the beginning of medical school” (5). This idea that prevention can best be utilized during their first and second year of school is one of the reasons why medical student cardiovascular health should be monitored and evaluated.

This study reports in part a detailed examination of the initial data gathered from an ongoing longitudinal study at the Philadelphia College of Osteopathic Medicine. It focuses on certain clinically relevant components of the electrocardiogram (ECG), specifically the QT wave interval as well as overall characteristics of the ECG, and the vector of electrical conduction through the heart i.e. the electrical axis, along with an evaluation of blood pressure abnormalities in these cohorts of students during the first two years of medical school. The rationale for this approach was based on a review of the initial data gathered, and a preliminary analysis which indicated a disparate number of abnormal ECG tracings between male and female medical student participants as well as a significant difference in their abnormal blood pressure readings. Documented changes will be further analyzed in association with certain life-style behaviors in these and similar cohorts of medical students in later phases of this longitudinal study and will be reported elsewhere.
Chapter 2

Background

ECG monitoring

The ECG tracing provides a record of the electrical activity of the heart that precedes the mechanical contraction of the heart muscle as well as documentation of heart rate and rhythm all of which provide important diagnostic information. The standard 12-lead electrocardiogram is a non-invasive method of monitoring the heart's electrical activity that is conveyed to the body surface. Six electrodes are placed on the chest surrounding the heart, one electrode is placed on each arm, and one electrode is placed on the left leg (a ground electrode is placed on the right leg). The nine electrodes together provide twelve unique perspectives of the heart’s electrical activity, or a “twelve-lead” ECG (Figure 1).

Figure 1. An illustration of electrode placement for recording a 12 lead ECG (6).
Electrical Signal Conduction Pathway

The synchronous beating of the heart is maintained by the transmission of the electrical signal through a specialized conduction pathway through the heart muscle. The electrical signal arises in the sinoatrial (SA) node located high in the wall of the right atrium near the entrance of the superior vena cava. It is the heart's normal pacemaker, automatically initiating impulses at a more rapid rate than any other part of the conduction system (Figure 2.)

Figure 2. An illustration of the pathway of electrical signal conduction through the heart (7).

Internodal pathways distribute the electrical stimulus to atrial muscle cells as the impulse travels from the sinoatrial node to the atrioventricular node. The ventricular conducting cells include those in the AV bundle and the bundle branches, as well as the Purkinje fibers, which distribute the stimulus to the ventricles of the heart.
**ECG Analysis**

1. The ECG Tracing

The electrocardiogram consists of a series of repeating wave patterns that are used to evaluate heart rate, rhythm and conduction of the electrical signal through the heart muscle (Figure 3). The figure below illustrates the various defined components of a normal ECG wave. The P wave represents atrial contraction and the QRS complex represents the depolarization of the right and left ventricles.

![ECG Wave Pattern](source://accessmedicine.com)

2. The QT Interval

The QT Interval refers to the elapsed time from the start of the QRS complex until the end of the T wave. It represents the total duration of electrical activity, including depolarization and repolarization, in the ventricles of the heart. The duration varies according to the individual’s heart rate; the faster the heart rate, the shorter the QT interval. It can be inferred that the more stressed or physically active a person is, the shorter their QT interval due to a faster heart rate. “A rate-related ("corrected") QT interval, QTc, can be calculated as...
QT/ R-R (R wave to R wave) and normally is 0.44 s. (9). Although the normal QTc interval range is equal to or below 0.44 seconds long, QTc’s tend to be a bit longer in women. This can be due to physical stature, physical condition, diet and exercise.

When analyzing the QTc, there are only two possible abnormalities: short and long QTc intervals. A short QTc interval is considered less than 0.35 seconds and a variety of factors may be associated with its development. The most common include congenital short QT syndrome, hypercalcaemia and the effects of digoxin. The digoxin effects are usually viewed as normal in individuals taking this drug although heart function should be monitored closely (10). A long QT interval may be associated with hypocalcaemia, drug effects, acute myocarditis, and long QT syndrome. Long QT syndrome is hereditary in some cases and results in a prolonged ventricular repolarization. Many anti-arrhythmic drugs cause a similar prolongation by slowing down the myocardial conduction and repolarization of the heart. These effects if not monitored and addressed can lead to sudden cardiac death and other medical problems. An interesting link between QT intervals and Body Mass Index has been proposed although additional supportive evidence is required; a BMI out of the normal range for their height and weight may result in abnormal QT intervals and variations (11).

3. Additional Parameters

Additional parameters contributing to an abnormal ECG that were considered in this study include: Early Repolarization Pattern, Pre Excitation Syndrome, Premature Ventricular Contraction, and Intraventricular Conduction Defect.

- Early repolarization is “characterized by J point elevation manifested either as terminal QRS slurring (the transition from the QRS segment to the ST segment) or notching (a positive deflection inscribed on terminal QRS complex) associated with concave upward
ST-segment elevation and prominent T waves in at least two contiguous leads” (12) (Figure 4).

Early repolarization pattern was commonly noted on the ECG tracing. Recent studies suggest that the condition may not be as benign as previously thought. A relationship between early repolarization and sudden cardiac arrest had been reported (14) and other observations have noted that the transient appearance of global J waves might be indicative of a highly arrhythmogenic substrate (15).

Figure 4. An illustration of J-point ST elevation (13).

- Preexcitation occurs when an atrial impulse is conducted in an anterograde (atria to ventricle) fashion down an AV accessory pathway before the AV node-His-Purkinje axis begins depolarization. How this manifests clinically and on the ECG depends on the speed at which the atrial impulse is conducted down the accessory pathway into the ventricular myocardium as compared to the AV node-His-Purkinje axis (Figure 5). This early ventricular depolarization manifests on the ECG as both a short P-R interval and a slurred upstroke in the R wave, referred to as the delta wave. It is associated with the development of Lown-Ganong-Levine Syndrome as well as Wolff-Parkinson-White Syndrome (17).
Premature ventricular contractions (PVCs) are early depolarizations of the myocardium originating in the ventricle. They are often seen in association with structural heart disease and represent increased risk of sudden death, yet they are ubiquitous, even in the absence of identifiable heart disease. They may cause troubling and sometimes incapacitating symptoms such as palpitations, chest pain, presyncope, syncope, and heart failure.

Premature atrial contractions (PACs) are contractions in the atria of the heart that occur too early in the rhythm sequence. Abnormal electrical impulses that originate in the atria outside of the normal conduction pathway signal the atria to beat prematurely. An extra beat occurs sooner than normal which in turn causes the subsequent beat to be more forceful within the atria. (Figure 6)
-Intraventricular conduction defect is characterized by a QRS complex that is wider than 0.12 seconds. This prolonged QRS causes a delay in the conduction tissue usually within the left or right bundle branches and is a useful indicator of chronic heart failure (19) (Figure 7).
**Axis Deviation**

“The cardiac axis is an indicator of the general direction that the wave of depolarization takes as it flows through the heart (Figure 8). The flow of electrical activity through the heart is fairly uniform, as it normally passes along a well-defined pathway” (10).

![Diagram of Cardiac Axis]

Figure 8. The limits of normal and abnormal QRS axis are summarized in the diagram above (8).

Generally the axis is referred to by its angle. A rule of thumb is: “if the QRS complexes are predominately positive in leads I and II, the cardiac axis is normal” (10). A normal axis can range up to positive 120 degrees and down to negative 30 degrees. For the purposes of this study, an axis range of 0 to 90 degrees was considered normal.

Left axis deviation refers to the range below negative 30 degrees. The most common causes and contributing factors include left anterior hemiblock, Wolf Parkinson White syndrome, inferior myocardial infarction and ventricular tachycardia. Generally a “predominantly positive QRS complex in lead I and a predominantly negative QRS complex in lead II means left axis deviation” (10). Right axis deviation occurs when the angle is above positive 90 degrees. Associated with this is right ventricular hypertrophy, Wolf Parkinson...
White syndrome, anterolateral myocardial infarction, dextocardia and left posterior hemiblock. Generally a “predominantly negative QRS complex in lead I and a predominantly positive QRS complex in lead II means right axis deviation” (10).

**Blood Pressure Analysis**

Blood pressure is recorded using two different parameters, systolic and diastolic pressure. The systolic reading “measures the pressure in the arteries following the contraction of the heart whereas the diastolic reading reflects the pressure in the arteries between heart beats while the heart chambers are relaxed and refilling with blood” (21). Normal blood pressure is considered to be less than 120 (systolic) and less than 80 (diastolic). For the purposes of this study and in accordance with the American Heart Association’s guidelines, any blood pressure reading that was recorded at or above 120/80 was considered abnormal (22).

Unfortunately, “about one in three (33.5%) U.S. adults have high blood pressure” (21). Blood pressure is an important parameter to consider when analyzing an individual’s cardiovascular health as “a strong linear relationship exists between the per cent of questionable ECG’s and the systolic and diastolic blood pressures” (23). Thus, the need for preventive measures and treatments of high blood pressure remains at the forefront for addressing cardiovascular risk. Abnormal blood pressures are associated with many other systemic health issues: “it is a strong precursor of hypertension, atherosclerosis and cardiovascular events” (24).
The American Heart Association outlines three key explanations for the importance of a healthy blood pressure. First, being in the proper range reduces one’s risk for the blood vessel walls becoming overstretched and injured. Second, it reduces the risk of heart attack or stroke and the associated development of heart failure, kidney failure and peripheral vascular disease. Third, overall health is supported when adequate tissue perfusion is maintained (26).
Chapter 3

Objectives and Hypotheses

Objectives

1. To identify and measure any Q-T wave interval abnormalities, cardiac axis vector abnormalities, and Blood Pressure abnormalities that occur over the course of the first and second year of medical school in these student volunteer subjects during the initial years of this longitudinal study.

2. To compare frequency of documented abnormalities in these male and female medical students.

3. To document any abnormal cardiovascular parameters that occur in these students during the first two years of medical school.

Hypotheses

Within these study cohorts of first and second year medical students:

1. Q-T wave interval abnormalities will occur with greater frequency in male than in female medical students.

2. Cardiac Axis Vector abnormalities will occur with greater frequency in male than in female medical students.
3. Blood Pressure abnormalities will occur with greater frequency in male than in female medical students.

4. The incidence of abnormal Q-T wave, Cardiac Axis Vector, and Blood Pressure recordings will exceed clinically established, normal, age and sex adjusted ranges for these parameters.

5. The number of other, episodic, abnormal features noted in the cardiologist-investigator's review of the ECG tracings exceeds clinically established, normal, age and sex adjusted frequency expectations for these parameters.
Chapter 4

Materials and Methods

Recruitment

Student members of the graduating class of 2012 and 2013 were contacted by letter describing the study, offering the opportunity to volunteer for the study, and providing the contact information of the investigators for interested students. Volunteers were presented with the guidelines, study objectives, answers to their questions or concerns and informed consent obtained.

Enrollment

A health questionnaire was administered to identify any history of cardiovascular problems as well as any prescription or over-the-counter drugs that might affect cardiovascular function (an exclusion criteria).

An initial ECG tracing and Blood Pressure reading were obtained and only those individuals with a normal ECG (per review by the study cardiologist), blood pressure and appropriate responses to the health questionnaire were enrolled in the study.

Demographics

This bi-phasic single-arm longitudinal study used a random selection algorithm to recruit student-subjects for participation. The chart below presents the demographics for the two cohorts of enrollees:
Table 1. Demographic information for the two cohorts of medical students who participated in the initial phases of this study. The BMI range is based on and calculated from height and weight data obtained at the time of enrollment into the study.

<table>
<thead>
<tr>
<th>Year</th>
<th>Males</th>
<th>Females</th>
<th>Age Range</th>
<th>BMI Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>2012– 1st &amp; 2nd Year</td>
<td>19</td>
<td>20</td>
<td>21 to 35</td>
<td>18.244 to 35.438</td>
</tr>
<tr>
<td>2013 – 1st Year</td>
<td>7</td>
<td>20</td>
<td>22 to 29</td>
<td>17.697 to 32.485</td>
</tr>
</tbody>
</table>

**Procedures**

Blood pressure and ECG tracings were obtained during bi-weekly sessions over the course of the first and second academic years for each subject. These data were coded to protect the privacy of the subjects. The study cardiologist read, evaluated, annotated, dated, and signed each ECG, and returned it to the principal investigators within one month of the date that the ECG was obtained. Subjects received a copy of their blood pressure readings and ECG with the accompanying evaluation. When any abnormalities were present in their blood pressure readings or ECG evaluation, the subjects were encouraged to share this information with their personal health-care provider.

**ECG Measurement**

All ECG tracings were recorded at a speed of 25 mm/sec, using standard lead positions with the subject supine on an examining table according to AHA guidelines (27).
**Blood Pressure Measurement**

All Blood Pressure measurements were obtained with the subject in the seated position according to the American Heart Association Guidelines (22).

**QT Interval Measurement**

All QTc interval measurements were obtained directly from the examination of the ECG and then corrected with the heart rate by using Bazett’s formula.

**Cardiac Axis Vector Measurement**

All cardiac axis measurements were obtained directly from the examination of the ECG.

**BMI Measurement**

All BMI measurements were calculated using each participant’s height and weight and computed using an electronic BMI calculator according to standard procedures (28).

**ECG Abnormalities**

Study cardiologist scored ECG strips according to adult guidelines and his expert opinion.

**Data Analysis**

Data were analyzed by calculating upper and lower 95% binomial confidence intervals for each abnormally occurring parameter and was weighted according to the number
of observations for individual subjects. Fisher’s exact test was used to compare differences in mean percentage of abnormal parameters (29). To summarize, the following is a step by step account of how the data was collected:

1. Tallied the number of abnormal and normal readings each subject had throughout the year.

2. Found the percentage of abnormal readings for each subject.

3. Calculated the mean percentage of abnormal readings for males and females.

4. Performed a Fisher's exact test, found P value and calculated 95% confidence intervals.
Chapter 5
Results

Blood Pressure
Abnormal blood pressures were documented for two different cohorts of subjects during each of the three academic years evaluated (Figure 10, 11, (same cohort) and 12 (different cohort). Blood pressure readings $\geq120/80$ mm Hg were considered to fall out of the normal range. Blood pressure was recorded as abnormal if either the systolic, diastolic or both were outside the normal range. For each of the study periods, the mean percentage of abnormal values was significantly higher for males than for females. During their first year of medical school, males in the graduating class of 2012 had an abnormal blood pressure reading 60% of the time they were tested; in contrast to 36% for females in the same class. For this same group during their second year, abnormal blood pressure readings were recorded on average 40% of the time for males and 20% for females. For the graduating class of 2013 (a different cohort of students), similar results were found, with males experiencing abnormal blood pressure readings 48% of the time they were measured, compared to an average of 13.4% for females.

The final comparison of blood pressure was carried out by combining average abnormal blood pressure data for females in both of the first year classes of 2012 and 2013, and combining it to average abnormal blood pressure data for males in both of the first year classes of 2012 and 2013 this data is summarized in Table 2 below.
Figure 10, 11, and 12. A plot of abnormal blood pressure readings for male and female students during their first and second academic years in medical school.
Figure 13. A plot of the two first-year cohorts abnormal blood pressure readings combined by sex.

<table>
<thead>
<tr>
<th>Year</th>
<th>Males</th>
<th>Females</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>2012 – 1st year</td>
<td>60.00%</td>
<td>36.00%</td>
<td>.0144</td>
</tr>
<tr>
<td>2012 – 2nd year</td>
<td>40%</td>
<td>20%</td>
<td>.001</td>
</tr>
<tr>
<td>2013 – 1st year</td>
<td>48%</td>
<td>13.4%</td>
<td>.001</td>
</tr>
<tr>
<td>2012, 2013 combined 1st year</td>
<td>34.8%</td>
<td>17.3%</td>
<td>.0003</td>
</tr>
</tbody>
</table>

Table 2. A comprehensive summary of the BP data for all first year females vs all first year males in the classes of 2012 and 2013. The p values indicate the level of significance of the comparisons (Fisher's Exact Probability test).
**QTc Interval**

QTc interval readings > 0.44 seconds were considered to fall out of the normal range. Although a small number of abnormal QTc intervals were documented for both cohorts of subjects during each of the academic years evaluated (Figure 14, 15 and 16 below), no statistically significant difference between the sexes was found for any class year.

The final comparison of QTc wave intervals was carried out by combining average QTc data for females in both of the first year classes of 2012 and 2013, and combining it to average abnormal QTc data for males in both of the first year classes of 2012 and 2013. No statistically significant differences were found in the percentage of abnormal readings between males and females.
Figure 14, 15, and 16. A plot of abnormal QTc interval measurements for male and female students during their first and second academic years in medical school.
Figure 17. The two first-year cohorts abnormal QTc wave intervals combined and compared between sexes.

**Axis Deviation**

Abnormal axis deviations were documented for both cohorts of subjects during each of the academic years evaluated (Figure 18, 19 and 20 below). Axis vectors outside the range of 0 to 90 degrees were considered to fall out of the normal range. A comparison of the mean percentage of abnormal values between male and female subjects in all class years resulted in no statistically significant differences. However, for the class of 2012 second year, a comparison of mean percentage of female values contrasted to male values, revealed a p value of 0.083 suggesting a trend towards significance.
Figure 18, 19, and 20. A plot of mean abnormal axis deviation vectors for male and female students during their first and second academic years of medical school.
Abnormal ECG Readings

Abnormal duration of the QRS complex, atypical presentation of "P", QRS and T waves, length of P-R and QTc intervals, baseline elevation/depression served as the basis for evaluating the normalcy of the ECG record as noted by the study cardiologist’s expert opinion. These abnormalities were documented for both cohorts of subjects during each of the academic years evaluated (Figure 21, 22 and 23 below). A comparison of the mean percentage of abnormal values between first year medical school male and female subjects in both class years resulted in no statistically significant differences (Figure 24).

The final comparison of ECG's was carried out by combining average abnormal ECG data for females in both of the first year classes of 2012 and 2013, and comparing it to average abnormal ECG readings for males in both of the first year classes of 2012 and 2013. No statistically significant differences in the incidence between male and female participants were observed. Furthermore, due to the absence of guidelines for cardiovascular abnormalities among young adults in the 20 to 30 age range there can be no real comparison made.
Figure 21, 22, and 23. A plot of abnormal ECG readings for male and female students during their first and second academic years of medical school.
Figure 24. A plot of mean abnormal ECG's for male and female students during their first and second academic years of medical school.
**Calculated Body Mass Index**

The BMI for all participants was calculated from the height and weight at entry into the study. An abnormal BMI was considered to be a value of 25 and above. There was no statistical differences between the sexes which may have been due to the disproportionate number of females compared to males enrolled for the class of 2013.

![Percentage of BMI’s over 25 in Class of 2012, 2013](image)

Figure 25. The percentages of BMIs over 25 in both the first year classes of 2012 and 2013 for male and female participants.
Chapter 6

Discussion

Overview

<table>
<thead>
<tr>
<th></th>
<th>Class of 2012 (1st year)</th>
<th>Class of 2012 (2nd year)</th>
<th>Class of 2013 (1st year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blood Pressure</td>
<td>Males – 60%</td>
<td>Males – 40%</td>
<td>Males – 48%</td>
</tr>
<tr>
<td></td>
<td>Females – 36%</td>
<td>Females – 20%</td>
<td>Females – 13.4%</td>
</tr>
<tr>
<td>QTc Interval</td>
<td>Males – 4.12%</td>
<td>Males – 1.54%</td>
<td>Males – 0%</td>
</tr>
<tr>
<td></td>
<td>Females – 2.63%</td>
<td>Females – 1.85%</td>
<td>Females – 1.25%</td>
</tr>
<tr>
<td>Axis Deviation</td>
<td>Males – 9.21%</td>
<td>Males – 9.47%</td>
<td>Males – 14.3%</td>
</tr>
<tr>
<td></td>
<td>Females – 5.26%</td>
<td>Females – 6.94%</td>
<td>Females – 1%</td>
</tr>
<tr>
<td>Abnormal ECGs</td>
<td>Males – 5.88%</td>
<td>Males – 23.84%</td>
<td>Males – 31.26%</td>
</tr>
<tr>
<td></td>
<td>Females – 12.54%</td>
<td>Females – 22.73%</td>
<td>Females – 25.78%</td>
</tr>
</tbody>
</table>

Table 3. An overview of the cardiovascular parameters included in this study.

**Blood Pressure**

For each of the study periods, the mean percentage of abnormal blood pressure measurements was significantly higher for males than for females, which confirms hypothesis #3 formulated at the inception of this study. Gender is reported as an important biological determinant of vulnerability to psychosocial stress, with men being generally rendered more susceptible to hypertension and cardiovascular disease and women to depression and anxiety disorders (30). The Canadian Heart and Stroke Foundation's 2010 Annual Report on Canadians' Health, “A Perfect Storm,” states that there are "more than 250,000 young Canadians in their 20s and 30s with high blood pressure"(31). This number was self reported by two age groups with 164,431 (2.5%) reporting high blood pressure in the 20 to 34 year old group and 343,638 (7.1%) in the 35 to 44 year old group (31). This is one of the only databases that focuses on the cardiovascular health of this particular segment.
of the general population. While it does not specifically target medical students it raises awareness of the importance of hypertension as a risk factor in this age group, and gives indirect support to the findings reported here. Most of the subjects within the study are in their early to late 20’s and this age range is reflective of other professional educational programs, and challenging high-performance work environments. The stress of excelling in one’s career field is extremely intense, and the association between lifestyle and cardiovascular parameters such as blood pressure are incorporated into the succeeding phases of this ongoing study.

**QTc Interval**

QTc wave interval changes are utilized as part of the clinical interpretation of the ECG with respect to the repolarization characteristics of the ventricles (32). Heart rate correction is required in the analysis of the repolarization duration and requires a stable sinus rhythm without sudden changes in the RR interval. It is interesting to note that heart rate data for these participants (reported in a linked study) indicated a low percentage of heart rate abnormalities, which is consistent with the low percentage of QTc wave abnormalities calculated. Although a small percentage of abnormal QTc intervals were documented for both cohorts of subjects during each of the academic years evaluated there were no statistical differences in the incidence between male and female participants. Therefore, the initial hypothesis that QTc wave interval abnormalities would occur with greater frequency in male than in female medical students was not supported by this analysis of the initial data from this study.
QRS Axis Vector Deviation

Axis vector deviations were considered to be abnormal when they were outside the range of 0 to 90 degrees. Although the normal variations are mainly anatomical differences in the Purkinje distribution system or in individual differences in the musculature of the heart, a number of abnormal conditions of the heart can cause axis deviation beyond the normal limits. There is evidence that there is little difference in the normal QRS axis vector between males to females (33).

For the class of 2012 second year females compared to male participants, a p value of 0.083 was calculated suggesting a trend towards significance; a mean percentage of 6.94 for females and 9.4 for males were found to have abnormal axis deviations throughout their second year. Interesting to note is that abnormal left axis deviation predominated in the males and abnormal right axis deviation in females for the class of 2012. Non-pathologic left axis deviations can occur at the end of deep expiration, when lying supine because the abdominal contents press upward against the diaphragm, and quite frequently in obesity as the diaphragm presses upward against the heart continuously due to increased visceral adiposity. Since ECG's were performed in the supine position for all participants this variable is an unlikely contributor.

A survey of BMI measurements in association with those subjects with left axis deviations revealed no incidences of abnormal BMI's but does not rule out the non-uniform deposition of visceral adipose tissue. Non-pathologic right axis deviations most often occurs in tall, lanky individuals whose hearts hang downward. This association cannot be corroborated in our study population. No statistically significant results or trends were found when comparing the sexes during the other academic years. The hypothesis, “cardiac axis
vector abnormalities will occur with greater frequency in male vs. female medical students,” was not supported by the data analysis. However, the trend for the class of 2012 (second year) towards significance may or may not be of cardiovascular significance and warrants a further examination of cardiac axis measurements in the future phases of this study.

**ECG Abnormalities**

ECG abnormalities increased between the first and second years of medical school in both males and females. This increase, however, was not statistically significant ($P = 0.53$, $P = 0.44$ and $P = 0.15$). In the class of 2012, females had a higher mean percent of abnormal ECGs in the first year of medical school compared to males, while males showed a trend to have higher mean percentage in the second year compared to females. The presence of abnormal components of the heart’s electrical conduction warrants further analysis and research to conclude whether or not problems are presenting themselves at an earlier stage than normal. Because stress can speed the onset of health issues, the underlying problems that an individual may eventually develop may have their origins during their first and second year of medical school. The finding of these abnormalities in the medical school population, although a cause for concern, may also be looked upon as a positive finding because there is a possibility that a predisposed problem can be resolved or treated so that further complications do not occur as with aging.

Regardless of the lack of statistically significant comparative data between male and female participants, with the exception of blood pressure, the fact that abnormal parameters can be documented regardless of sex for the study cohorts from the graduating classes of 2012 and 2013 focuses attention on the need to further characterizing this study population’s
cardiovascular health. The table below summarizes all the abnormal cardiovascular parameters documented:

<table>
<thead>
<tr>
<th>Class of 2012 (1\textsuperscript{st} Year)</th>
<th>Class of 2012 (2\textsuperscript{nd} Year)</th>
<th>Class of 2013 (1\textsuperscript{st} Year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abnormal BP</td>
<td>Abnormal QTc Intervals</td>
<td>Abnormal QRS</td>
</tr>
<tr>
<td>Abnormal QTc Intervals</td>
<td>Abnormal PR</td>
<td>Abnormal BP</td>
</tr>
<tr>
<td>Axis Deviation</td>
<td>Abnormal PR</td>
<td>Abnormal QTc Intervals</td>
</tr>
<tr>
<td>Abnormal PR</td>
<td>Abnormal HR</td>
<td>Axis Deviation</td>
</tr>
<tr>
<td>Abnormal QRS</td>
<td>Sinus Arrhythmia</td>
<td>Abnormal PR</td>
</tr>
<tr>
<td>Abnormal HR</td>
<td>Bradycardia</td>
<td>Abnormal HR</td>
</tr>
<tr>
<td>Sinus Arrhythmia</td>
<td>Tachycardia</td>
<td>Sinus Arrhythmia</td>
</tr>
<tr>
<td>Bradycardia</td>
<td>PAC</td>
<td>Bradycardia</td>
</tr>
<tr>
<td>PAC</td>
<td>ST-T Abnormal</td>
<td>T wave abnormality</td>
</tr>
<tr>
<td>First Degree Heart Block</td>
<td>T wave abnormality</td>
<td>Nodal Rhythm</td>
</tr>
<tr>
<td></td>
<td>Abnormal baseline</td>
<td>Tachycardia</td>
</tr>
<tr>
<td></td>
<td>T wave inversion</td>
<td>T wave inversion</td>
</tr>
<tr>
<td></td>
<td>Early Repolarization</td>
<td>Flipped T wave</td>
</tr>
<tr>
<td></td>
<td>Pre Excitation Syndrome</td>
<td>Accelerated Nodal Rhythm</td>
</tr>
<tr>
<td></td>
<td>PVC</td>
<td>ST-T abnormality</td>
</tr>
<tr>
<td></td>
<td>IVCD</td>
<td>Flat T waves</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Primary AV Block</td>
</tr>
</tbody>
</table>

Table 4. Summary of Documented Cardiovascular Abnormalities

The hypothesis that, “the number of other, episodic, abnormal features noted in the review of the ECG tracings exceeds clinically established, normal, age and sex adjusted frequency expectations for these parameters,” is impossible to prove or disprove because there is scant literature documenting cardiovascular abnormalities among young adults in this age range. Similarly, the hypothesis stating, “the incidence of abnormal QT wave, cardiac axis vector, and blood pressure recordings will exceed clinically established, normal, age and sex adjusted ranges for these parameters,” also is impossible to prove or disprove because of the lack of published documentation that can be used for comparative analyses. The gap within the literature is one of the main reasons why this data analysis is crucial and breaks new ground in an underexplored area of cardiology.
Suggested Improvements

A major area for improvement in the implementation of this study is the consistency in subject attendance at established data gathering sessions for recording the blood pressure, heart rate and ECG readings. It is of extreme importance that organized and persistent contact with each participant is implemented and continued throughout the entire course of the year; a number of participants did not regularly report for their scheduled readings and some participants withdrew before the end of each academic year. Commitment to the study should be addressed with each participant.

One improvement that has been implemented in the next phase of this study is the administration of a questionnaire at each recording session to gather information regarding lifestyle patterns; specifically those pertaining to diet, exercise, sleep, caffeine intake and study schedules etc all of which may impact the cardiovascular system. If cardiovascular abnormalities occur, an analysis of such a survey could reveal relevant associations. This dynamic way of interpreting one’s overall cardiovascular health gives a more complete picture for each participant.

Future Considerations

The goal of this longitudinal study was to continue the investigation of cardiovascular parameters and associated lifestyle for the next five medical school classes throughout their first and second year academic years in order to gain a better understanding, documentation and further characterization of the cardiovascular risks and abnormalities that develop in this population of medical students and which may provide new insights into an underexplored
area of research. Hopefully, as more information is uncovered and analyzed, prevention and awareness will be extended to all young professionals and graduate students. Cardiovascular health is extremely important to each and every individual and the greater the awareness of predispositions, possible risks and abnormalities, the better their healthcare and treatment will be.

One investigational report stated that, “modifiable cardiovascular risk behaviors are widely prevalent among medical students and increase with years spent in medical college. Promotion of supportive environments that strengthen student-based approaches and strategic delivery of health education are essential in order to target the risk behaviors among our future doctors” (34). Due to the intense stress that accompanies medical school, the students should have effective healthcare and be able to monitor their health throughout each year. Another source revealed that, “it is paradoxical that while doctors are the primary providers of healthcare, they represent one of the most unhealthy professional groups” (35). This paradox is alarming and must be changed because the future of healthcare rests in the hands, hearts and minds of medical students across the country.

Medical school students are the future doctors of this society, thus prevention and action must be taken in institutions where health and science are the backbone of their missions and core values. The continuation of this project is an excellent way to gather further evidence and support of crucial information. There is much hope that successful data and findings are within reach and can make an impact on other institutions and individuals in the near future.
References


24. American Diabetes Association

26. American Heart Association


28. National Insitutes of Health (NIH)


